TM 11-453

WAR DEPARTMENT

TECHNICAL MANUAL

SHOP WORK

March 11, 1942

TECHNICAL MANUAL

SHOP WORK

CHANGES No. 1 | WAR DEPARTMENT, WASHINGTON 25, D. C., 20 March 1944.

TM 11-453, 11 March 1942, is changed as follows:

LESSON 1

CLASSIFICATION, CARE AND MAINTENANCE OF TOOLS

* * * * * * *

6. **Maintenance of screwdrivers.**—The screwdriver is * * * only, driving screws. Do not use it as a chisel, nailpuller, can opener or **for any job that may damage the tool.** The screwdriver is * * * he commonly uses. Some errors of maintenance and use of this tool are illustrated in **figures 3a, 3b, 3c, and 3d.**

The broad flat * * * of uniform thickness.

Figure 3d

To repoint a screwdriver blade, square the point of the tip and bevel the edges and the flat surfaces of the blade. This may be done in the following manner:

Select a flat steel file. Clean as indicated in lesson 4, paragraph 1, if the teeth of the file are clogged. Set up the work so that the elbow will be level with the surface being filed.

Use a vise, if available, to secure the screwdriver in place, leaving both hands free for guiding the motion of the file.

To square the point of the tip, the screwdriver is secured in a perpendicular position, with the tip pointing upward (fig. 5①). File with a diagonal stroke, making the tip smooth and straight and squared with the edge of the blade.

To bevel the edges of the blade the screwdriver is placed in a horizontal position (fig. 5②). The upper edge of the blade is filed at a slight angle, using a diagonal stroke. When the edge is filed to the required width, the other side of the edge is turned up, and is filed in the same manner.

To bevel the flat surfaces of the blade (fig. 5③), follow the same procedure as described in beveling the edges of the blade. (Lesson 4, paragraph 1, contains additional filing directions.)

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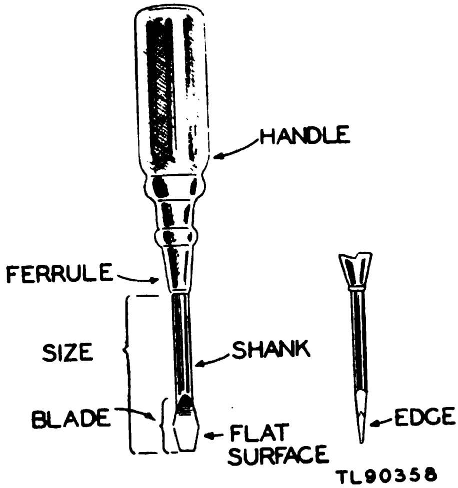


Figure 4 (Added.)

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

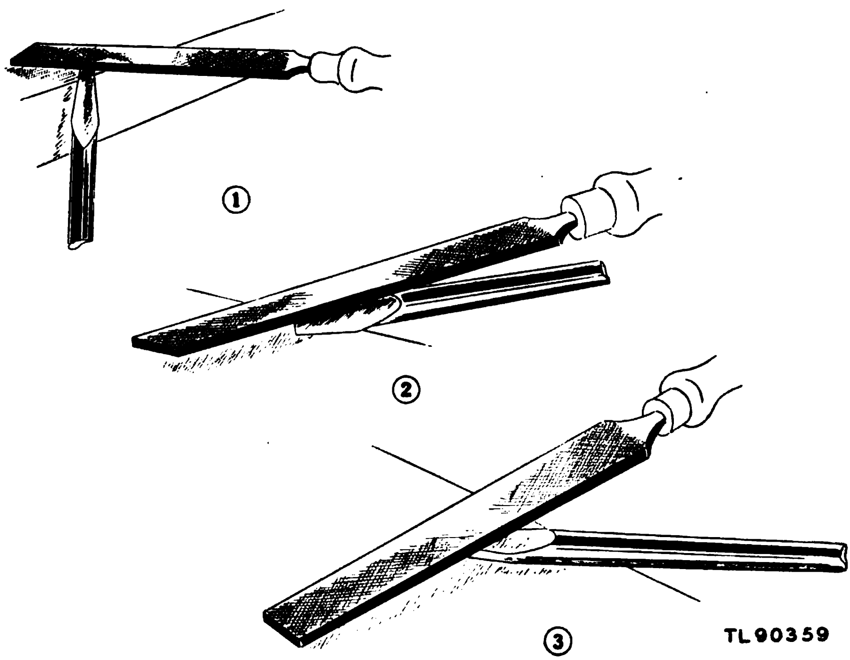


Figure 5 (Added.)

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

Some safety precautions * * * hands or face.

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

7. Wood bits (Added).—Wood bits are sharpened by filing. The filing tools should include a small, half-round file, an auger bit file with safe edges, and a small triangular or square file. All wood bits have the same general features and are sharpened in the same manner. The two parts which may need sharpening are the cutting

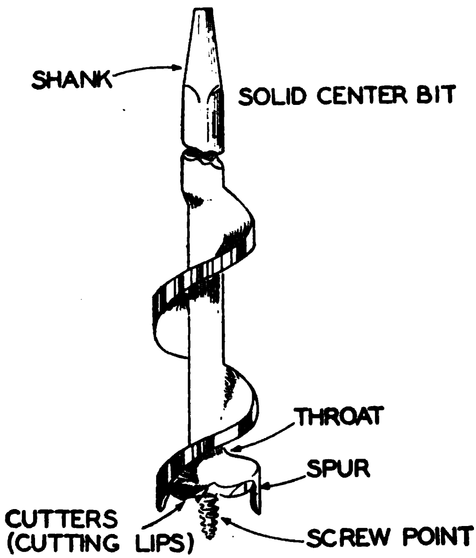


Figure 6 (Added.)

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

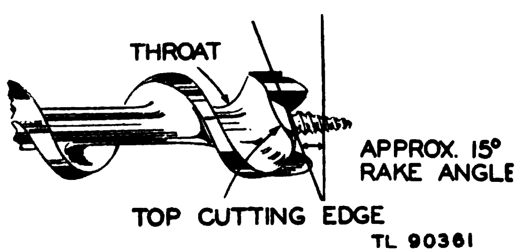
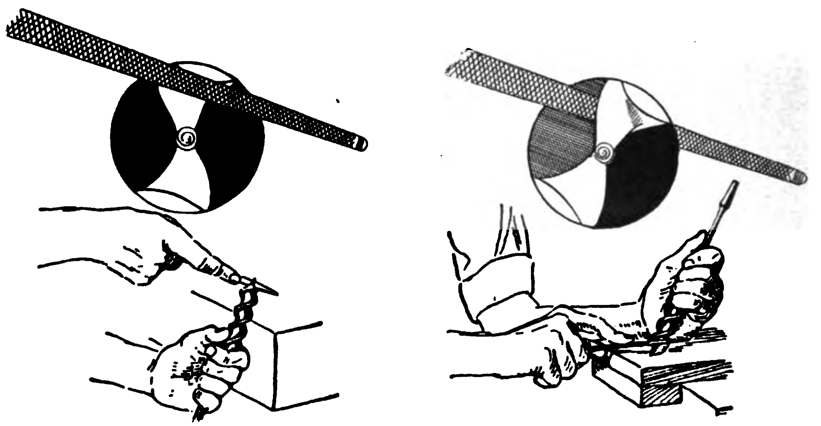


Figure 7 (Added.)

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

lips or cutters (fig. 6) and the spurs. With the usual types of wood bits, touch-up filing is worked through the throat (fig. 7), using either the half-round file (if the throat is rounded and small) or the auger bit file (if the throat is open). Spurs are always sharpened on the inside, never on the outside (fig. 8). An auger bit file should be used when sharpening spurs, because its uncut edges minimize accidental

cutting of the lip surface. If the bit is very dull, the top of the cutting edge should be filed (fig. 8). It is important that the original bevel be maintained and that the surface following the cutting edge be filed *flat* completely across its width. If only a small portion of the edge of the lip is filed, the rake angle of the bevel is lessened and the chip-lift-



SHARPEN AUGER BITS WITH A BIT FILE. FOR A KEEN EDGE ALSO WHET WITH A SLIPSTONE. SHARPEN THE SPURS ON THE INSIDE TO PRESERVE THE DIAMETER.

SHARPEN THE CUTTING EDGES ON THE TOP TO MAINTAIN THE CLEARANCE ON THE UNDER SIDE. THE CUTTING EDGES MUST BE KEPT EVEN.

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Figure 8 (Added.)

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

ing ability of the cutting edge is destroyed. The use of small stones on the filed surface will give the sharpened surface a polish which increases the cutting efficiency of the tool.

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

Review questions.—

* * * * * * *

9. Name the safety precautions to be observed when using a screwdriver.

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

LESSON 2

USE OF KNIFE AND PLIERS, WIRE SPLICES

* * * * * * *

7. Field wire splice.

* * * * * * *

b. Measure one plier's * * * in figure 1.

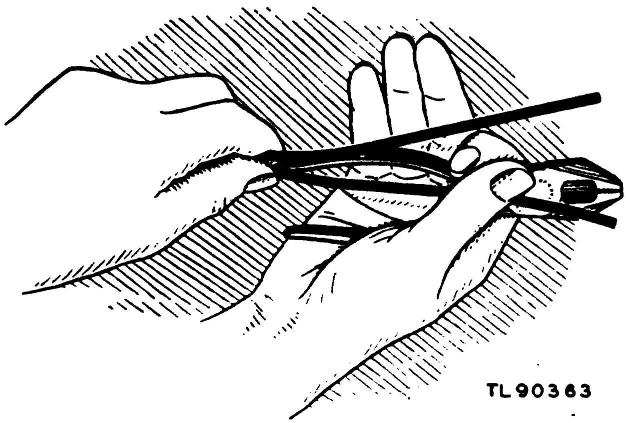

Figure 1

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

c. Crush and remove * * * in figure 2.

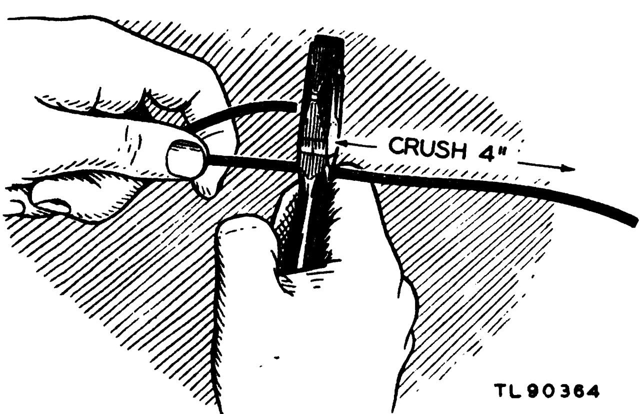

Figure 2a

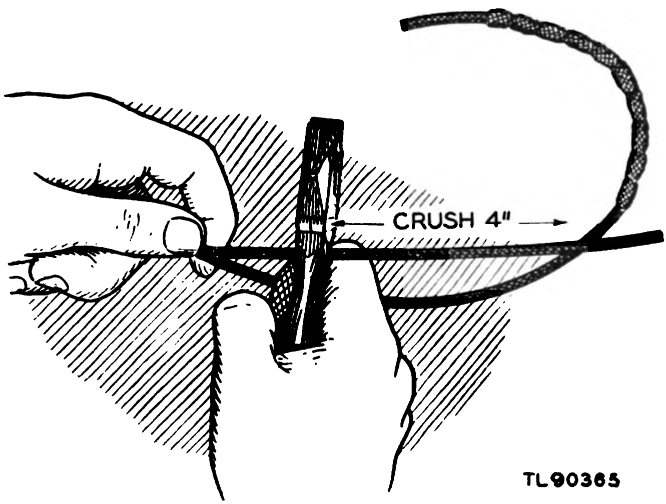

Figure 2b

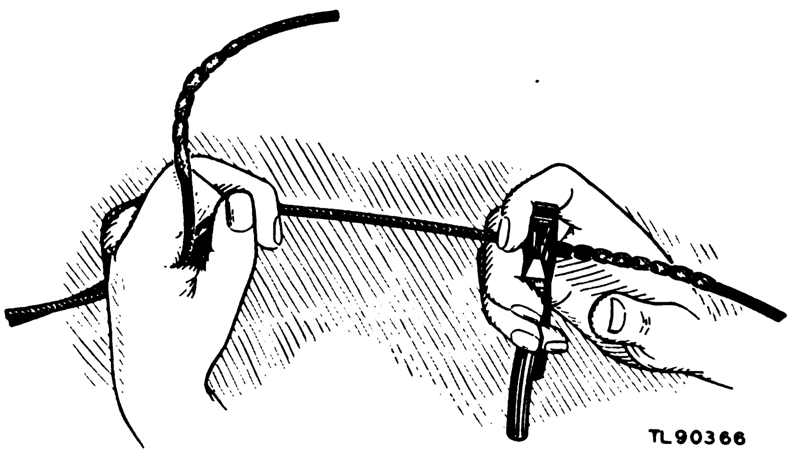

Figure 2c

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

* * * * * * *

d. **Place the wires to be spliced in the position as illustrated in figure 2d. Tie a square knot as indicated in figure 3.**

* * * * * * *

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

11. The field wire "T" splice.

* * * * * * *

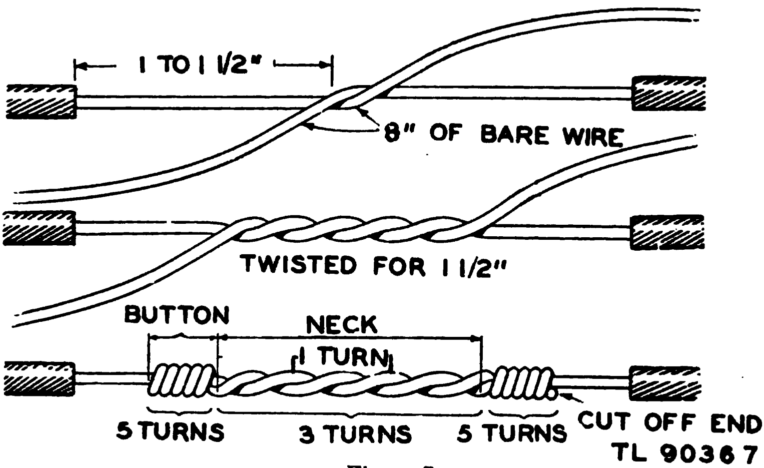

Figure 7

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

After the splice * * * in figure 8.

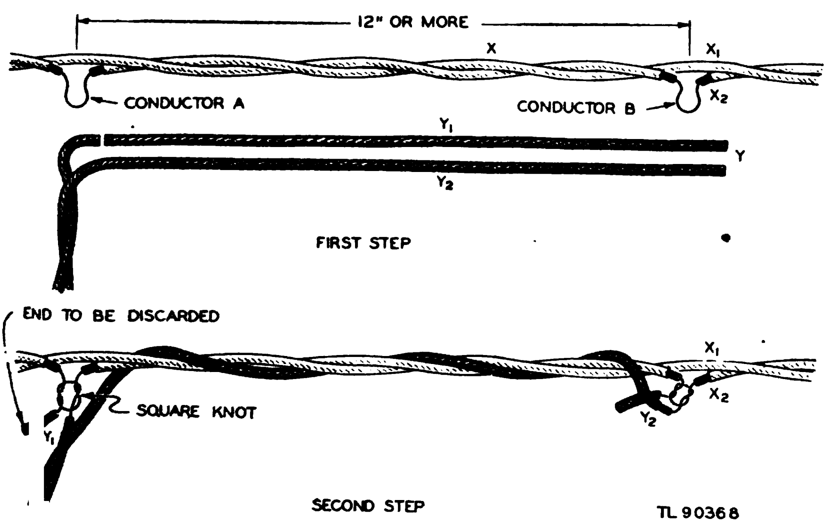

Figure 8

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

* * * * * *

Review questions.—

* * * * * * *

16. (Added.) How many complete turns are made in the buttons of the Western Union splice?

17. (Added.) How many turns are made in the neck of the Western Union splice?

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

LESSON 2

LABORATORY

Tools and materials.—

Knife, TL-29
Pliers, side-cutting
Pliers, long-nose
Pliers, diagonal
*Wire W-110
*Wire, bare copper, W-74 (104-mil bare hard-drawn copper, also known as wire 104)
*Seizing wire, 22-gauge bare copper

Items marked * are not placed on the memorandum receipt.

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

Procedure.—

* * * * * * *

Operation 3.—Using 104 bare copper wire and W-110, make a combination seizing wire splice.

---------------- Ins. check

Operation 4.—Using wire furnished, make a tap splice.

---------------- Ins. check

Operation 5.—Using wire furnished, make a Western Union splice. Submit all splices to instructor for approval.

---------------- Ins. check

* * * * * * *

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

LESSON 3

MEASURING AND GAUGING

1. Steel scale.

* * * * * * *

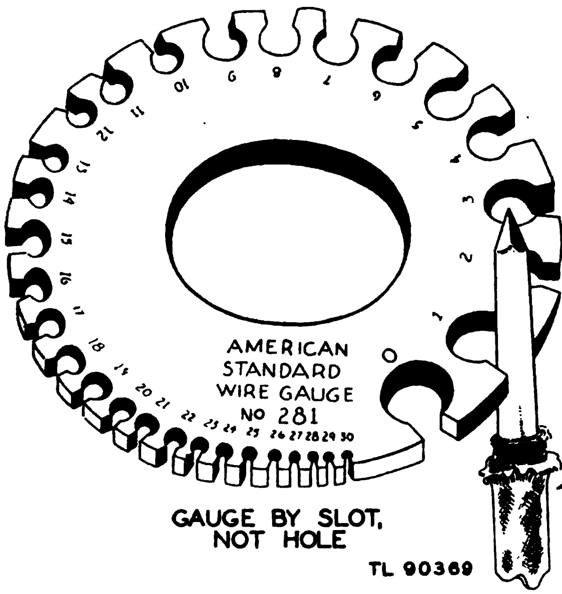

Figure 1

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

2. Wire gauges.—The wire gauge * * * *the copper wire.*

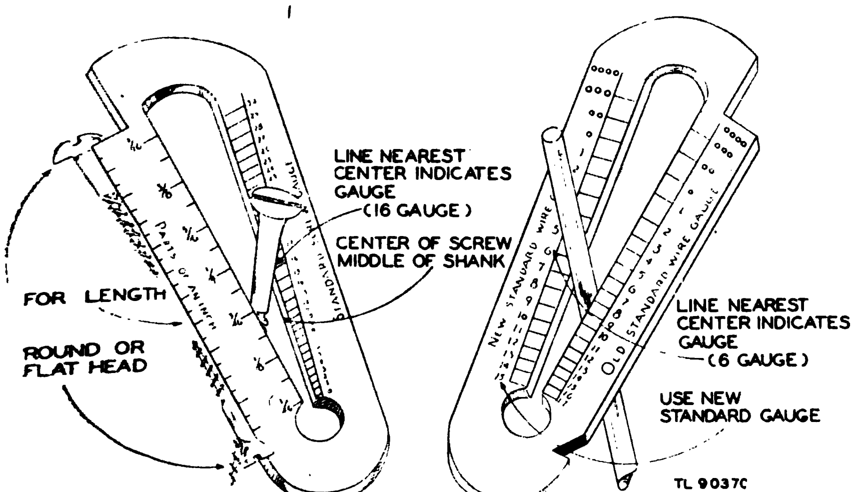

Figure 1.1 (Added.)

The circular wire * * * the correct gauge **(fig. 1.1).**

* * * * * * *

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

LESSON 4

METAL WORKING

* * * * * * *

6. Taps and dies.

* * * * * * *

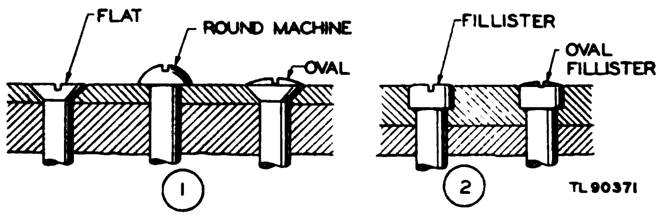

Figure 6

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

* * * * * * *

LESSON 4

LABORATORY

* * * * * * *

Procedure.—

Operation 1.—Using the ½-inch x 1-inch brass stock, square the ends with the files. **Drill and tap a hole for a 12–24 thread.**

----------------Ins. check

Figure 8 (page 38) is rescinded.

Operation 2.—**Using the brass rod furnished, and size 14–20 die, cut a ½-inch thread on one end only.**

----------------Ins. check

Operation 3.—**Using the length of iron stock furnished, cut ¼-inch from one end and square the ends of the remaining stock.**

----------------Ins. check

Operation 4.—**Cut a piece of sheet brass 1 inch square and square all sides.**

----------------Ins. check

Operation 5.—Cut a piece of iron plate and square it. Form the bracket shown in figure 9.

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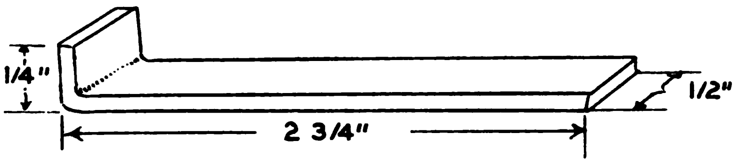

Figure 9

Operation 6.—Cut a piece of bakelite 1 inch square and square all sides.

________________Ins. check

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

LESSON 5 (page 58)

LABORATORY

(Wire Students Only)

Tools and materials for operations 1, 2, 3, 4, and 5.—

* * * * * * *

*4 pcs. Wire, copper, 104

* * * * * * *

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

Procedure.—

* * * * * * *

Operation 3.—Clean and tin one end of each of the four pieces of 104 copper wire. The tinned portion * * * will be secured.

________________ Ins. check

* * * * * * *

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

Tools and materials for operations 6 to 16 inclusive.—

* * * * * * *

*1 pc. 20-pr. switchboard cable
*1 ea. Brass rods, 1/4 inch x 12 inch

* * * * * * *

Items marked * are not placed on the memorandum receipt.

Inspect models on display board and table before doing any of the operations below.

* * * * * * *

Operation 9.—Place the pairs * * * wires in place. **If two brass rods are used,** lay the other rod * * * the terminal block.

________________ Ins. check

Operation 10.—Separate the first pair of wires **(blue with white mate).** Lay the white wire across the edge of the mounting strip so that it will be out of the way. Bend the coded **(blue)** wire into the notch of the top terminal of the second row. (The terminals are counted from the front to the back of the terminal block. **The pairs are counted from the top to the bottom of a vertical strip.)** The next step is to remove the insulation from the wire. **Using a pair of long-nosed pliers, and starting at a point marked by the notch, crush the insulation about 1 inch toward the end of the wire. Remove crushed insulation. Wind the loose ends of the insulation tightly around the wire with the fingers, and slip back about ¼-inch to facilitate the removal of enamel or tarnish. Enamel or tarnish may be removed by use of insulation strippers or the long-nose pliers. After the wire has been cleaned thoroughly, pull the insulation back and wind tightly so that the insulation comes under the terminal but does not enter the notch. Wind the bare wire around the terminal, making one complete turn, beginning and ending in the notch. Excess wire is removed by severing it in the notch. When working with wire of a larger gauge (18 gauge or larger), or on terminals that are not very rigid, severing may be accomplished by pulling the wire taut and bending it from side to side.**

Solder the connection and inspect for the faults listed below:

* * * * * * *

c. Rosin joints. (Not enough heat.)

d. Solder not adhering to wire. (Must be unsoldered and wire scraped.)

After the connection has been inspected, and all faults corrected, if the student is in doubt as to whether the connection has been soldered properly, have the instructor check it before soldering others. Continue with the coded wires until all 20 have been soldered.

________________ Ins. check

* * * * * * *

Operation 12.—Lash another piece * * * block mounted horizontally. **Wires should be fanned through the bottom of the**

horizontal strip. Place and solder * * * instructor for approval.

_______________Ins. check

Operation 13.—**Place five pairs of cross-connecting wires from the vertical protector strip to the top punchings of the horizontally mounted terminal block.** This wire is not dressed back against the fanning strip. Each pair of cross-connecting wires should have approximately 3 inches of slack. **These wires are connected and soldered on the horizontal block as in operation 10. In connecting to the vertical protector strip, the insulation should come up to, but not enter, the notch. The method outlined in operation 10 for removing insulation and attaching wires to punching will be followed. Solder is applied on the face of the punchings.** Check the connections for faults and submit to the instructor for approval.

_______________Ins. check

* * * * * * *

Operation 16.—Rescinded.

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

LESSON 5A

WIRING OF RADIO EQUIPMENT, CORDS AND PLUGS

(For Radio Students Only)

* * * * * * *

3. Cable wiring.—Cable wiring is * * * work being done.

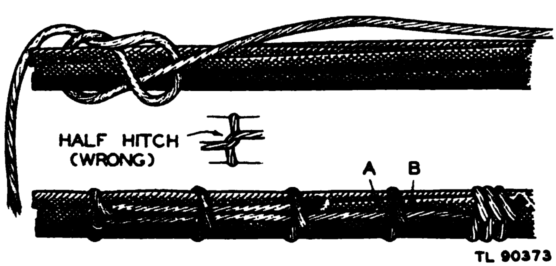

Figure 9

A figure eight * * * then cut off. **The wires are laced together with a lock stitch. Do not use a half-hitch. The half-hitch will not hold the form together if the lacing cord is broken. At the points marked A and B in figure 9, the twine must be on the under side. If either A or B is on top when**

the stitch is made, it is called a half-hitch. When the lacing is completed, the twine is anchored by placing two or three stitches behind the last stitch of the form. See figure **9**.

Figure 10. Rescinded.

* * * * * * *

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

Review questions (Added).—

1. Should bus wire be insulated if it is likely to come in contact with other wires in a radio set?
2. How long is the bent-over part of the butt joint?
3. What is done to a stranded wire before a satisfactory loop can be made?
4. When is cable wiring used?
5. Will cordage shielding in any case be found on the outside of the rubber jacket?
6. What is the proper tool to use in removing the rubber jacket from a cord?
7. What trouble may develop if all the strands of a conductor are not soldered into place?
8. Should the cutting blade of a knife be used to clean wire?

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

LESSON 5A

LABORATORY

(For Radio Students Only)

Tools and materials for operations 1 to 6 inclusive.—

* 1 ea. Blow torch * 4 pcs. Wire, copper, **104**

* * * * * * *

Items marked * are not placed on memorandum receipt.

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

Procedure.—

* * * * * * *

Operation 3.—Clean and tin one end of each of the four pieces of **104** copper wire. The tinned portion * * * will be secured.

---------------- Ins. check

* * * * * * *

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

Tools and materials for operations 7 to 14 inclusive.—

1 each Soldering iron TL-117
1 each Pliers, 6-inch side-cutting (TL-13)
1 each Pliers, long-nose (TL-126)
1 each Pliers, diagonal (TL-103)
1 each Knife TL-29
1 each Small screwdriver
1 each Chassis
1 each Plug PL-50
1 each Plug PL-61
***1 ea. File, 10-inch, with handle**
1 ea. File, card
*6 pcs. Wire No. 14, enameled
*1 bundle Wire, for chassis wiring
*3 Terminals, mounted on block
*1 pc. Cordage CO-130
*1 pc. Cordage CO-138

Items marked * are not placed on the memorandum receipt.

Inspect models on * * * *the operations below.*

* * * * * * *

Operation 10.—One satisfactory loop must be completed to fit the machine screw furnished.

---------------- Ins. check

* * * * * * *

Operation 13.—Rescinded.

* * * * * * *

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

LESSON 6

WOODWORKING

* * * * * * *

3. Laying out the work.

* * * * * * *

Marking gauge.—This tool consists * * * along the grain. **Do not use the tool across the grain.**

* * * * * * *

Transferring the dimensions.—A pencil with * * * cannot be used. **A pencil or knife used in conjunction with a square or st[raight] edge should be used to mark across the grain. The** kn[if]e or pencil should have the upper end tilted away from the square or [ed]le.

(Figure 1)

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

Mallets.—The wood mallet * * * wooden pins, etc. Malle[ts a]re sometimes made of lead, brass, **or plastic.**

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

12. Claw hammer.—The claw hammer * * * for removing nails.

If it is necessary to hammer a nail with the use of only one hand, proceed as follows: insert the nail between the hammer claws (fig. 3.1①), with the head of the nail against the base of the hammer head, so that the nail remains rigidly in position. Drive the nail deep enough with the first blow so that it will remain in the wood until struck again with the face of the hammer.

Another method for hammering a nail with one hand is shown in figure 3.1②. Grasp the hammer head so that the side of it will be used for driving. Hold the nail head against the side of the hammer, and drive the nail deep enough with the first blow so that it will remain in place to be struck again in the usual manner.

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

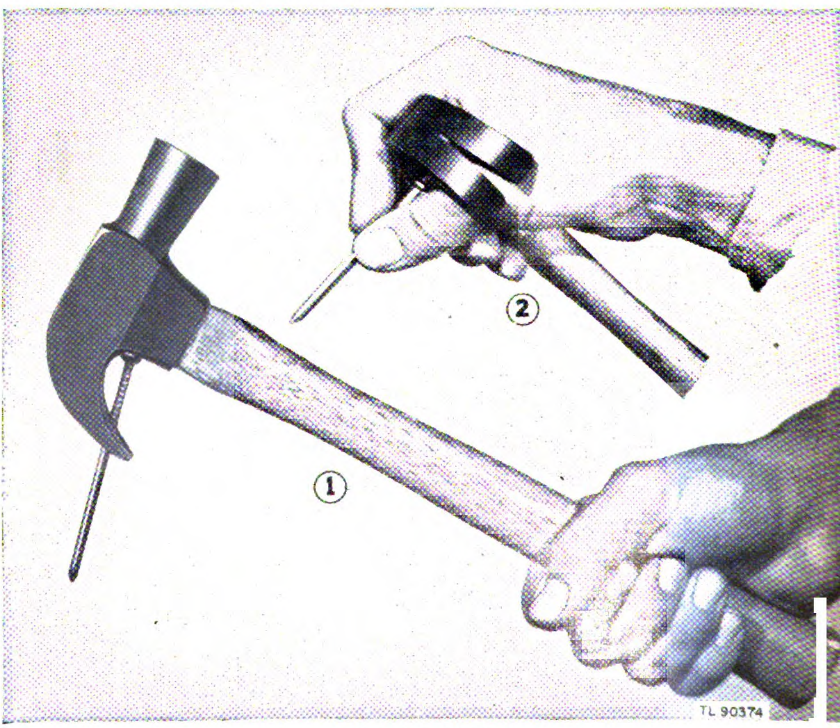

Figure 3.1 (Added.)

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

16. Fastening devices.

* * * * * *

Nails.—The wire nail * * * by the figure.

Common Wire Nails (Added.)

Size	Length (inches)	Gauge number	Diameter (inches) approximate	Approximate number to 1 pound
2D	1	15	5/64	876
3D	1¼	14	5/64	568
4D	1½	12½	3/32	316
5D	1¾	12½	3/32	271
6D	2	11½	7/64	181
7D	2¼	11½	7/64	161
8D	2½	10¼	1/8	106
9D	2¾	10¼	1/8	96
10D	3	9	5/32	69
12D	3¼	9	5/32	63
16D	3½	8	5/32	49
20D	4	6	3/16	31

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

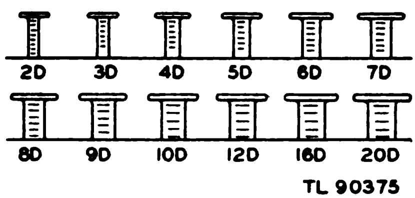

Figure 5 (Added.)

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

* * * * * * *

LESSON 7

LABORATORY

Tools and materials.—

* * * * * * *

*4 pcs. **104** copper wire.

* * * * * * *

I[illegible]ns marked * are not placed on the memorandum receipt.

* * * * * * *

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

LESSON 8

ROPES, SPLICES, KNOTS, AND BLOCKS

1. General information on rope.—

* * * * * * *

e. Selecting the size of rope for the work to be performed.—The approximate weight * * * fibres to break. Table 3, **page 130,** shows the proper size ropes for the various size blocks. (See rigging.)

* * * * * * *

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

2. The more common rope splices.—

* * * * * * *

b. Crown splice.—See figure 2 (b).

* * * * * * *

(6) Continue **the weaving in the following manner (fig. 2(b)F):**

(a) Place one of the loose strands over the nearest main strand; tuck it under the next main strand, pulling it at a 45° angle to the rope.

(b) Turn the rope counterclockwise until the next loose strand is forward. Place this strand over the nearest main strand and tuck it under the next main strand.

(c) Again turn the rope counterclockwise until the next loose strand is in the forward position. Follow the same procedure as in (b) above.

* * * * * * *

c. Eye splice.—The eye splice * * * in figure **3–A–D.**

(1) Untwist the strands * * * the eye required. **Be certain that the middle strand 2 is placed under the rope (fig. 3–A).**

(2) (Superseded.) Tuck strand 1 under one of the main strands of the rope at the point where weaving is to start (fig. 3–*B*).

(3) (Superseded.) Place strand 2 behind the rope (fig. 3–*A*).

(4) (Superseded.) Tuck strand 3 under the next main strand, directly below strand 1 (fig. 3–*B*).

(5) (Added.) Turn the rope over, and tuck strand 2 under the third main strand of the rope. This brings strand 2 through the main rope between strands 1 and 3 (fig. 3–*B*).

(6) (Added.) When all the ends have been tucked through for the first time, pull them down tight as in 3–*C*. Proceed to interweave the strands as follows:

(*a*) Pull strand 2 toward the top of the eye. Place strand 1 over the nearest main strand and tuck strand 1 under the next main strand. This should place strand 1 between strands 2 and 3.

(*b*) Place strand 2 over the nearest main strand and tuck it under the next main strand.

(*c*) Check the weaving to make certain that one main strand of the rope always separates the two other strands.

(*d*) Continue interweaving as in *b*(6) above until the total length of the interwoven strands, for ¼-inch rope, extends a distance of 4 inches. Add one tuck for each next larger standard size rope.

(*e*) Roll the splice between two flat surfaces under pressure as between foot and floor, and trim off surplus ends flush with the outside strands. The completed splice is shown in figure 3–*D*.

d. Short straight splice.—Short straight splice * * * of the rope. See **figure 3–E–G.**

(1) Untwist the strands * * * 10 to 16 inches. Butt the ends of the rope tightly together as in **figure 3–E** laying the strands * * * locking the strand.

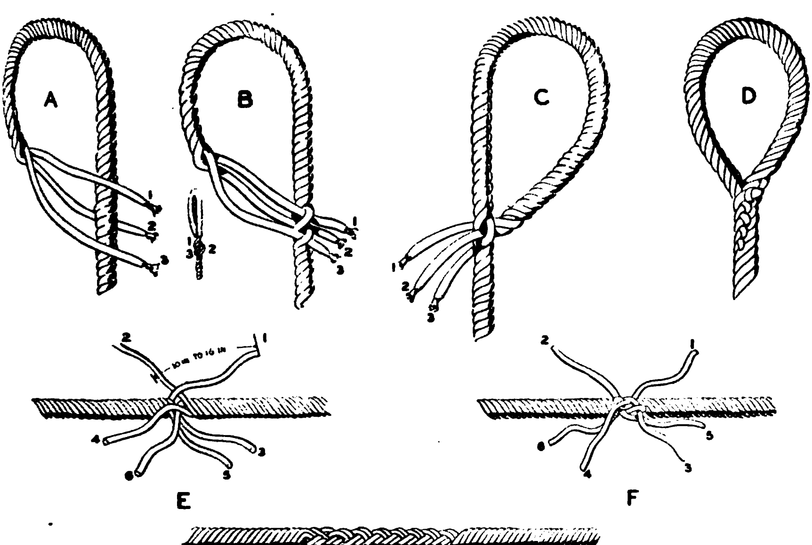

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Figure 3.

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

(2) (Superseded.) Hold the even-numbered strands and the rope tightly in the left hand. With the right hand, aided by the thumb and forefinger of the left hand, weave the odd-numbered strands in the following manner:

(*a*) Place one of the loose odd-numbered strands over the nearest main strand and tuck it under the next main strand, pulling it up to a 45° angle to the rope. Turn the rope counterclockwise until the next loose odd-numbered strand is forward. This strand, as well as the next, and last odd-numbered strand, are handled in the same manner as described above.

(*b*) The operation just explained is repeated with the even-numbered strands, producing an arrangement similar to that shown in figure 3–F. Continue the interweaving on alternate sides until its total length extends a distance of 4 inches for ¼-inch rope. Add another tuck for each next larger standard size rope.

(3) (Superseded.) Roll the splice between two flat surfaces under pressure (between the foot and floor), and trim off the surplus ends flush with the outside strands. The completed splice is shown in figure 3–G.

(4) Rescinded.

(5) Rescinded.

* * * * * * *

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

4. Blocks.

* * * * * * *

c. Manila rope snatch blocks.—Snatch blocks are * * * they will carry. **A snatch block may be defined as a single sheave block, with a hinged swivel hook.** Snatch blocks are illustrated in figure 21 (*b*).

* * * * * * *

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

LESSON 8

LABORATORY

Tools and materials.—

1 ea. Knife **TL–29**

* * * * * * *

Blocks for reeving will be found in the class room.

* * * * * * *

[A. G. 300.7 (14 Jan 44).] (C 1, 20 Mar 44.)

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:
J. A. ULIO,
Major General,
The Adjutant General.

U. S. GOVERNMENT PRINTING OFFICE : 1944

PREFACE

This text has been prepared by the Enlisted Men's Department of The Signal Corps School, to provide a progressive course in the use and maintenance of such woodworking and metal tools, as a soldier may be called upon to use in the various units of the Signal Corps.

Acknowledgement is made for the use of certain sections of Bell System Practices in lesson number eight, in the use, care, and maintenance of manila rope and blocks.

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TECHNICAL MANUAL No. 11-453

WAR DEPARTMENT, Washington, March 11, 1942

SHOP WORK

LESSON 1

CLASSIFICATION, CARE AND MAINTENANCE OF TOOLS

1. Classification.—Tools are divided into two general classes: machine tools and hand tools. Machine tools are usually driven by electric motors, and are used where the volume of work performed is great enough or the labor saved is sufficient to warrant their cost. Examples: lathe, circular and jig saws, drill presses and milling machines. Hand tools are those held in the hand, or those in which the operator furnishes the motive power. Examples: hand saws, knives, pliers, planes, miter boxes, etc.

Tools are further subdivided according to their use as layout, cutting, boring, driving, holding and sharpening.

2. Care of tools.—The work bench, classed as a holding tool, very seldom gets the care it should have. The top should be cleaned at the completion of each job, or daily, before leaving the shop. Vises attached to the work bench should be wiped off and inspected for rust at the same time. Do not allow trash to accumulate in the drawers. Heavy or rough work, assemblies which have sharp edges and other types of work that might gouge into the top of the bench should be handled from the floor or on special racks.

A salt, present in perspiration, causes rust to form on metal tools. Wipe all metal tools off with an oily rag, after a job has been completed; also before returning them to the store room.

The correct storage of tools plays an important part in their care. Cutting and boring tools should be placed in racks or drawers which will protect their cutting edges, and while in use on the work bench, should be placed so that their cutting edges will not come in contact with other tools. The rivets in the hinges of pliers and similar tools should

be oiled occasionally to keep them working freely. Layout tools must not be dropped, used as a pry, to drive screws or as a scraper. This abuse will render them inaccurate. Inspect the handles of all driving tools frequently, see that they are tight and free from checks and splinters. When tools are to be stored for some length of time, a lubricant such as vaseline or heavy gunoil should be spread over all metal parts. Thin oil breaks down and allows atmospheric moisture to corrode the metal. No mechanic, however expert, can do first class work with an unserviceable tool.

3. Maintenance of tools, shaping and sharpening.—Cutting and driving tools such as chisels, knives, twist drills, wood bits and screwdrivers must be correctly shaped and sharpened in order to perform first class work. Tools are shaped and large nicks removed from cutting edges by the use of carborundum wheels and stones, and grindstones. Oilstones are used for honing, which brings the cutting edge to the correct degree of keenness.

The grindstone is used for shaping and sharpening low temper tools such as adzes, hatchets, axes, cable knives, etc. Water is used on the grindstone to reduce the heat caused by friction, thus preserving the temper of the tool. The surface speed of wheels used to shape and sharpen high temper tools such as plane cutters, wood chisels, twist drills, metal working bits, etc., is too great to permit the use of a lubricant on the wheel itself. The temper of the tool is preserved during the grinding process by dipping it frequently into a can of water to keep it cool. Grindstones and carborundum wheels should revolve toward the user. This removes the metal from the cutting edge of the bevel and not from the heel.

A light oil is used on the surface of all flat stones, whether carborundum or oilstones, to prevent the small particles of metal removed from the tool from sinking into the stone. When the oil becomes dirty, wipe it off with a rag and place fresh oil on the stone. *Do not* grind or hone in one spot, work the tool over the entire surface of the stone. This keeps the surface level.

The following is a good test for a serviceable cutting edge. Place the cutting edge on the thumbnail, exert a light pressure, and draw the edge along the nail. If it "clings" to the nail the tool is correctly sharpened.

4. Sharpening the knife.—The knife is a double bevel tool, usually of low temper steel. *Do not grind the knife on the carborundum wheel.* If the nicks are too large to remove with a flat stone use the grindstone. The knife is sharpened by stroking first on one side of the blade and then on the other, moving the tool so that the cutting edge always meets the stone first.

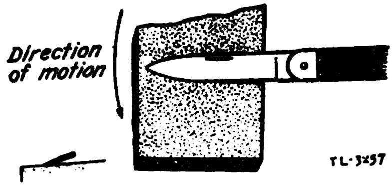


Figure 1

The correct stroking motion is illustrated in figure 1. The angle between the knife blade and the stone is about twenty degrees. After the nicks have been removed, hone to the correct cutting edge on the oilstone.

5. Chisels and plane cutters.—Plane cutters, chisels, gouges and similar single bevel cutting tools should first be ground square on the carborundum wheel. Check with a trysquare, testing from one edge of the tool only. With proper care, the single bevel type of tool need not be ground often. A few minutes spent in honing the tool on the oil stone will keep the cutting edge serviceable. A good general rule to follow is: If the honed part of the bevel exceeds one half of its total length the tool should be reground.

The angle of the bevel varies with the type of work to be performed. A good angle for general work is 25 degrees, soft wood or material is worked with a 20 degree bevel while hard wood requires a 30 degree bevel. Small nicks are removed by flat grinding on a carborundum stone. The bevel of the tool must be exactly parallel with the surface of the stone. Use one hand to guide the tool, the other to apply a

moderate amount of pressure and move the tool over the entire surface of the stone with a rotary motion as illustrated in figure 2.

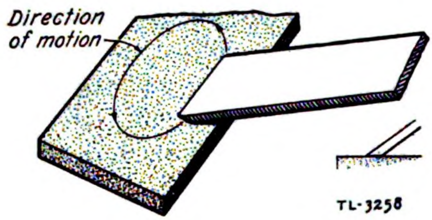


Figure 2

Use as small a circle as possible, as this gives better control over the tool. A rocking motion should be avoided, as this soon destroys the hollow grind obtained from the carborundum wheel and makes it practically impossible to sharpen the tool on a flat stone without regrinding. As the cutting edge of the bevel becomes thin, it will be noted that a burr or wire edge is formed on the back of the tool. This is removed by placing the back of the tool absolutely flat on the stone and using the rotary motion illustrated in figure 2. Plane cutters usually have a small portion of each end ground off to prevent them from biting into the wood being smoothed. When all nicks have been removed from the tool, hone to the correct cutting edge on the oilstone, using the procedure given above.

6. Maintenance of screwdrivers.—The screwdriver is probably more abused than any other tool. It is made for one purpose only, driving screws. Do not use it as a chisel, nailpuller, canopener or other jobs for which it is unfitted. The screwdriver is made of a very tough grade of steel due to the torque applied to it when driving screws. Every mechanic should have several screwdrivers each ground and correctly shaped to fit some screw he commonly uses. Some errors of maintenance and use of this tool are illustrated in figure 3.

The broad flat surfaces are ground slightly concave on the carborundum wheel or shaped with a file. The two surfaces must have an equal taper in order to keep the tip on the center line of the shank. *The end of the blade must have the sides parallel for the depth of the screw slot.* The tip should be square and of uniform thickness.

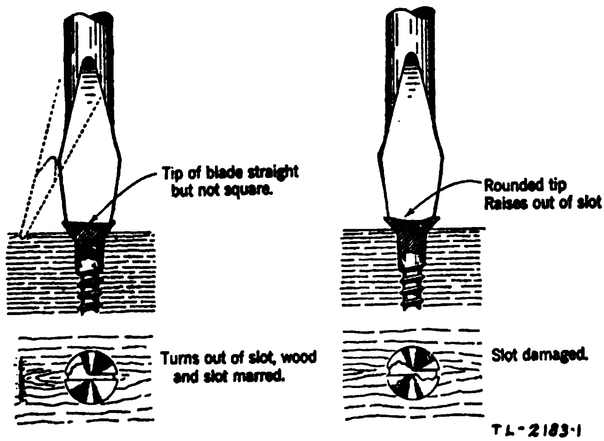


Figure 3a

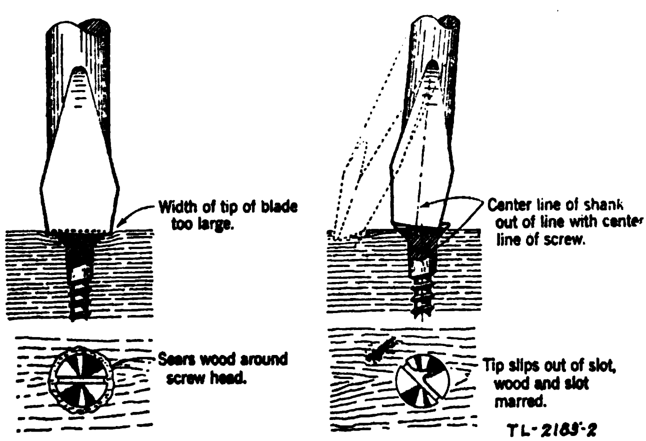


Figure 3b

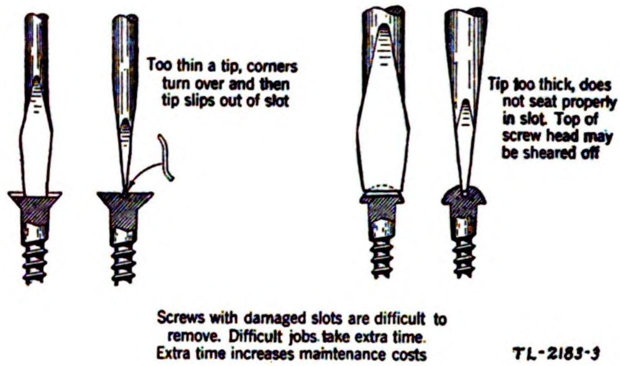


Figure 3c

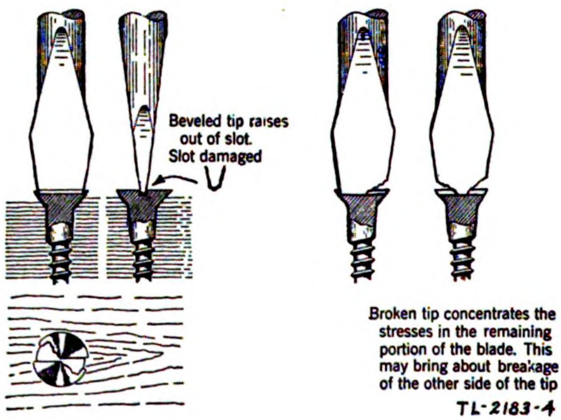


Figure 3d

Some safety precautions to be observed when using the screwdriver are, always drive a screw with the center of the screw and screwdriver in line; do not carry a screwdriver in a pocket, where injury may result through exposure of the point of the blade; never use a screwdriver with a bent blade and always work in such a manner that if the screwdriver slips, it will not cause injury to the hands or face.

The maintenance of twist drills and wood bits is an exacting job. The instructor will give group instruction in the correct procedure when necessary.

Review questions.—

The answers to all review questions will be found in the text. Do not consult the instructor regarding these questions unless you are unable to find an answer for them.

1. Name the two general classes of tools.

2. Name two things to be remembered about the care of hand tools.

3. Name two stones that are used to remove nicks from tools.

4. What is the oilstone used for?

5. What test is used to determine if a tool has a serviceable cutting edge?

6. Are knives and plane blades sharpened the same way?

7. How is the wire edge removed from plane blades and chisels?

8. Should a screwdriver with a bent blade ever be used to drive screws?

9. Name one safety precaution to be observed when using a screwdriver.

RESTRICTED

LESSON 1

LABORATORY

Tools and materials.—

Oilstone
Carborundum stone
Knife, TL-29
Wood chisel
Plane cutter
*Oilcan
*Rags

Items marked * are not placed on the memorandum receipt.

Procedure.—

Operation 1.—Using the oil and carborundum stones, sharpen the knife, TL-29. These stones break easily, and must be handled carefully.

............................Ins. check

Operation 2.—Sharpen the plane cutter. Follow instructions given in the lesson sheet.

............................Ins. check

Operation 3.—Sharpen the wood chisel. If the student is unable to determine if the plane cutter or wood chisel requires grinding, consult the instructor. Submit sharpened tools to instructor for approval.

............................Ins. check

Operation 4.—Examine one of the sets of screwdrivers displayed on bulletin board.

............................Ins. check

List the faults found below:

1.
2.
3.

LESSON 2

USE OF KNIFE AND PLIERS, WIRE SPLICES

1. **Electricians knife, TL-29.**—The three major parts of this knife are: handle, screwdriver and cutting blade. The screwdriver blade is provided with a lock, which protects the user when this blade is opened. Never have both blades open at the same time. The cutting blade is used to whittle soft materials and to remove insulation from wires. *Do not use this blade to scrape wires.* The screwdriver blade is used to drive small screws. If necessary, it may also be used to clean wires. When using the cutting blade, *do not cut toward the body.*

2. **Pliers, general.**—Pliers are classified according to their length and by the shape of their jaws. Examples: 6-inch side-cutting, 4-inch diagonals. Pliers are made in various lengths, with a wide variety of jaw shapes, each intended for some specific use. The important points to remember when using pliers are: keep them clean and free from rust, use a size and jaw shape that will do the work correctly, never use the pliers as a wrench or hammer. The three types of pliers used most commonly by signal specialists are: side-cutting, diagonal and long-nose.

3. **Side-cutting pliers, TL-13 (Commercial lineman's 6-inch side-cutting).**—This type of pliers is equipped with blunt jaws, which have a scored gripping surface, side wire cutters, parallel heel surfaces, and strong handles. The gripping surfaces do not close completely, as this would interfere with the cutters. These pliers are used for insulation crushing (use the heel), gripping, wire splicing, wire cutting and insulation stripping. When removing insulation, do not permit the jaws to touch bare wire. Never cut solid wire completely apart with pliers, as this may damage the cut-

ters. Nick it, then use the gripping part of the jaws to bend the wire back and forth until it breaks.

4. Long-nose pliers. TL-126 (Commercial 6- or 6½-inch).—Long-nose pliers have long, slender jaws, flat on the inside. They are usually scored on the inside of the jaw, near the end of the pliers. Some long-nose pliers are made with cutters, but the greater majority do not have them. Long-nose pliers are used for gripping, reaching places not readily accessible to the hand, holding wires, bending loops, attaching wires to terminals and punchings, skinning and splicing small wires.

Wire insulation is crushed with the long-nose pliers, providing they are not equipped with cutting jaws, by sliding the wire down the base of the jaws and squeezing down on the handles. The insulation can now be removed easily from the wire, and if necessary, the gripping surfaces of the jaws may be used to clean the wire.

Do not use this type of pliers to hold large objects, tighten nuts or bend the larger gauges of wire and sheet metal. Such practice soon springs the jaws, rendering the pliers unserviceable.

5. Diagonal pliers, TL-103, (Commercial 5-inch).—This type of pliers is equipped with cutting jaws, set at an angle of about fifteen degrees from the handles, making them more efficient in close places than side cutting pliers. The principal use of these pliers is cutting small gauge wires. These pliers should not be used to cut wires larger than 16 gauge steel or 14 gauge copper.

6. Wire splices, general.—The installation of wire systems, both field and permanent, requires the use of a variety of wire splices. The splice used will depend primarily on the types of wires to be connected. Regardless of the type of splice used, the following principals must be observed:

Thoroughly clean bare portion wires before joining.

A wire is not clean unless all tarnish or oxide is removed.

Do not nick the conductor, if the wire is stranded care must be exercised in removing insulation so that all strands remain intact.

Apply tape to splices on insulated wire, to restore the insulation and render the splice waterproof (see paragraph 12).

When splicing twisted pair, (field wire splice), the joints should be staggered at least 6 inches. This helps to prevent short circuits, and reduces the bulk of the splice.

7. **Field wire splice.**—The standard field wire splice, made in wires type W-110 and W-110-B, using copper seizing wire, is made as follows (also on older obsolete types of wire):

a. Cut the ends of both wires off square.

b. Measure one plier's length on one conductor (about 6 inches) and cut this length off, as illustrated in figure 1.

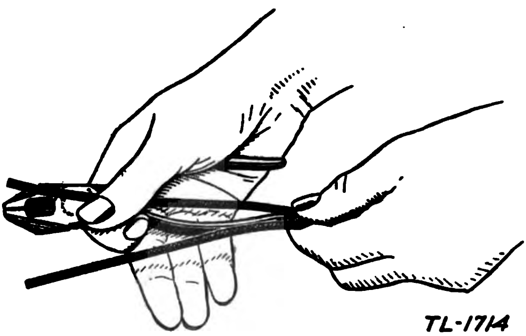


Figure 1

c. Crush and remove insulation from long and short conductor as indicated in figure 2.

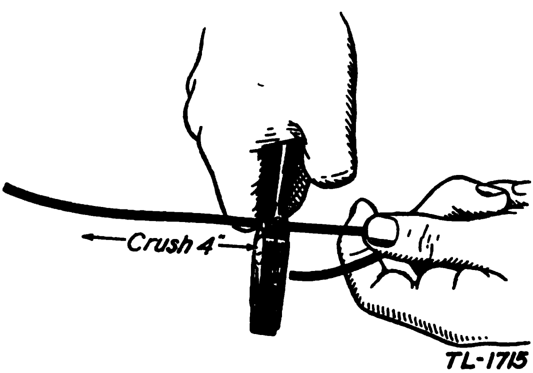


Figure 2a

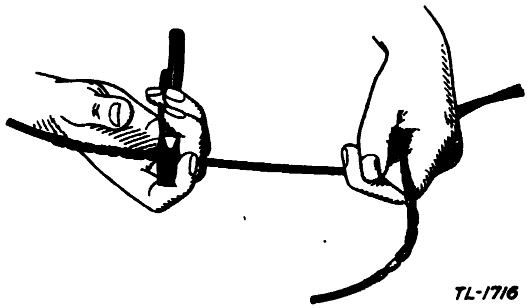


Figure 2b

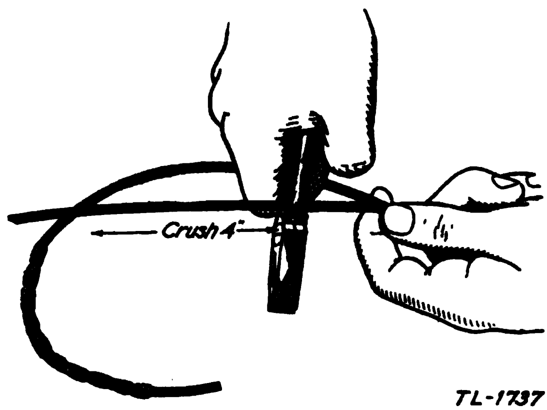


Figure 2c

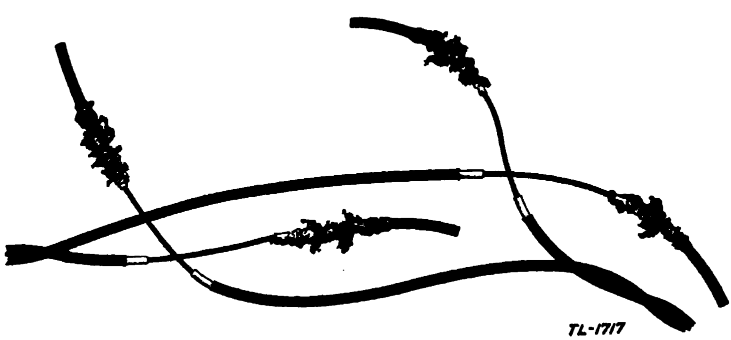


Figure 2d

d. Tie the square knot, using one long and one short conductor, as indicated in figure 3.

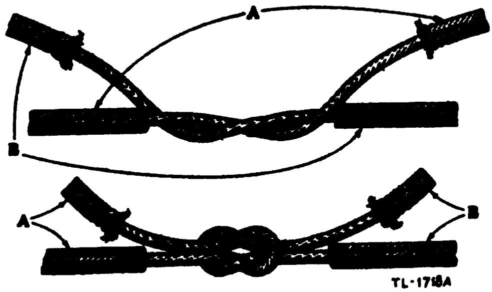


Figure 3

Note.—The square knot should be tied in both conductors without delay, to restore service to circuit before starting to perform the following operations:

e. Seize the splice as shown in figure 4.

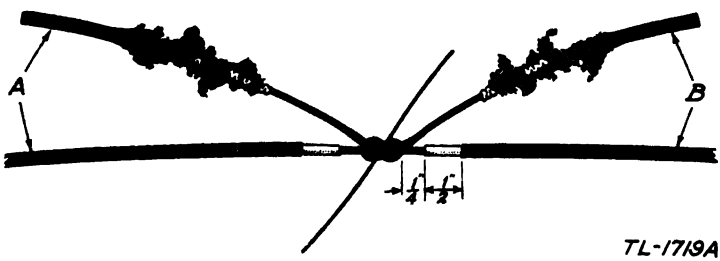


Figure 4a

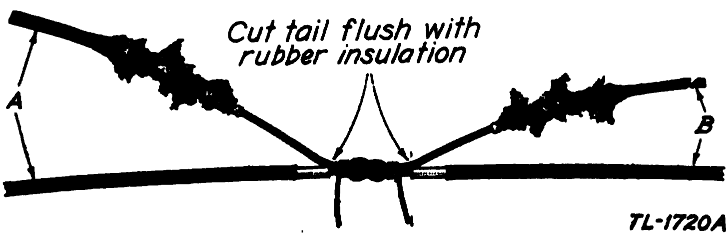


Figure 4b

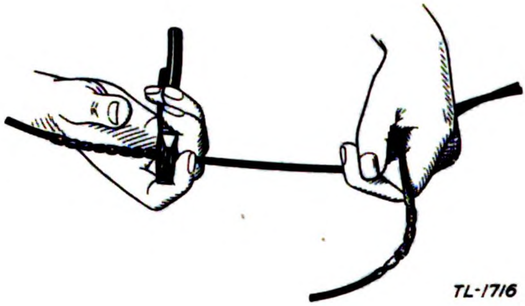


Figure 2b

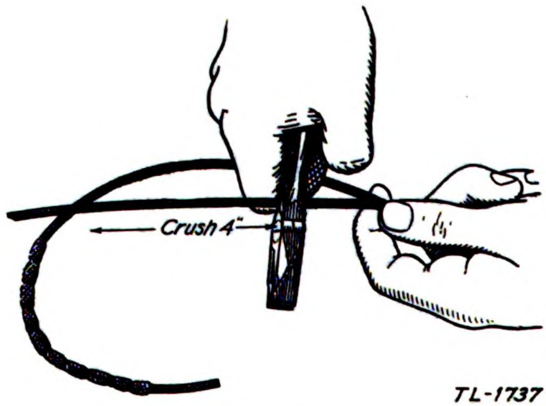


Figure 2c

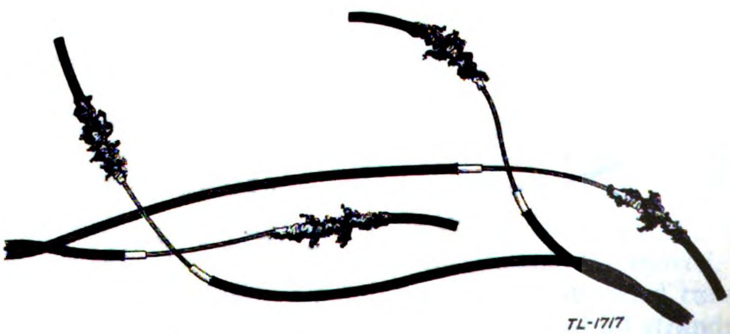
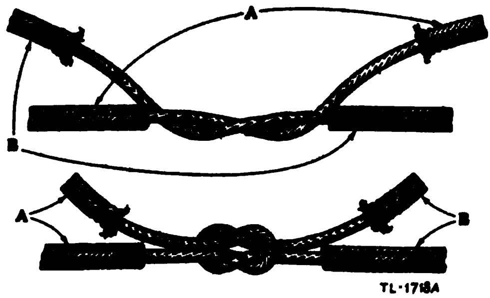


Figure 2d

d. Tie the square knot, using one long and one short conductor, as indicated in figure 3.



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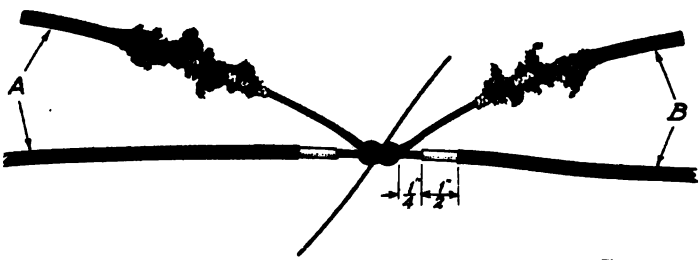
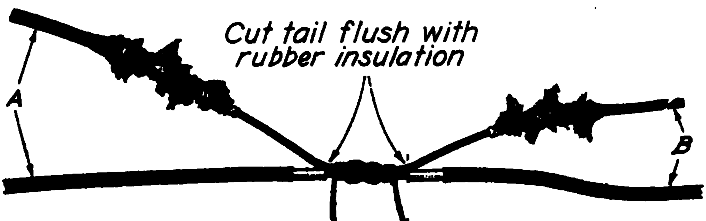


Figure 4a



Figure

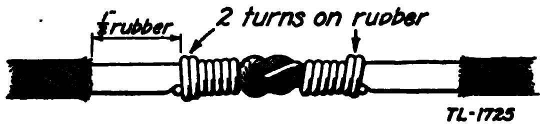


Figure 4c

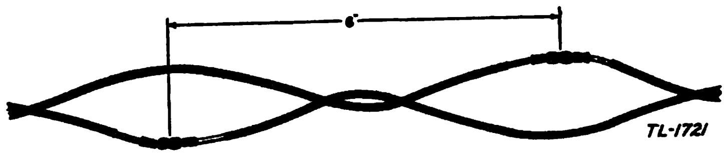


Figure 4d

8. Combination seizing wire splice.—This splice is used to splice a stranded conductor insulated wire to a solid conductor bare wire. Strip about one inch of insulation from the stranded wire and clean both wires so that they are bright and free of corrosion. Lay this end of the stranded wire along the solid wire. Begin the seizing by taking four turns with the seizing wire around the solid wire only, back of the stranded wire. Continue wrapping, including several turns over the insulation of the stranded wire, then over the bare end of the stranded wire, and finish with four turns over

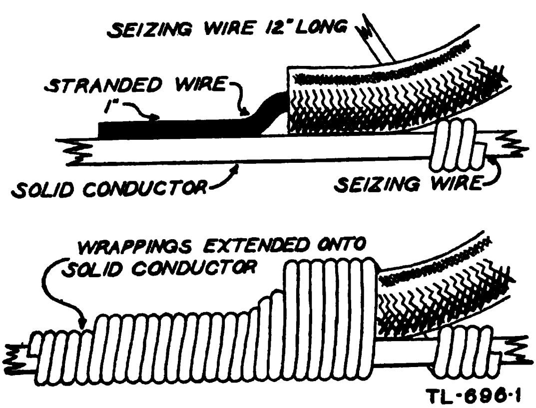
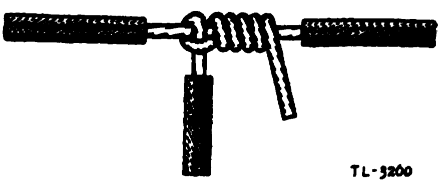


Figure 5

the solid wire only. Wrap the seizing wire tightly and draw the turns closely together. This splice will pull away very easily, therefore the stranded wire should be tied in to a fixed object near the splice to prevent any strain being imparted to the splice proper. See figure 5.

9. **Tap splice.**—This splice is used to tap a wire into a permanently installed line wire without cutting it. It may be made with either solid or stranded conductors, or a combination of both. To make the splice, remove 1 inch of insulation from the permanently installed wire and about 3 inches from the other wire. Lay the cleaned end of the tapping wire over the line wire. Make one wrap around the permanent wire with the tapping wire. Bring the end of the tapping wire across the standing part of the tapping wire, underneath the permanent wire, and with the remainder of the cleaned end of the tapping wire, place five close turns around the permanent wire. See figure 6.



TL-3200

Figure 6

10. **Western Union splice.**—The Western Union splice is used when splicing two solid wires together. Strip the insulation from the ends of both wires for about 8 inches and clean them so that they are bright and free of corrosion. Make the splice as illustrated in figure 7. The twisted portion, composed of three complete turns is called the "neck." The five close turns at each end are known as the "buttons." The wires in the neck should be in close contact with each other. Cut the ends of the buttons off as closely as possible, being careful not to leave a sharp point that will puncture the tape wrapping.

11. **The field wire "T" splice.**—This splice is used to tap a field wire circuit without causing interruption to service.

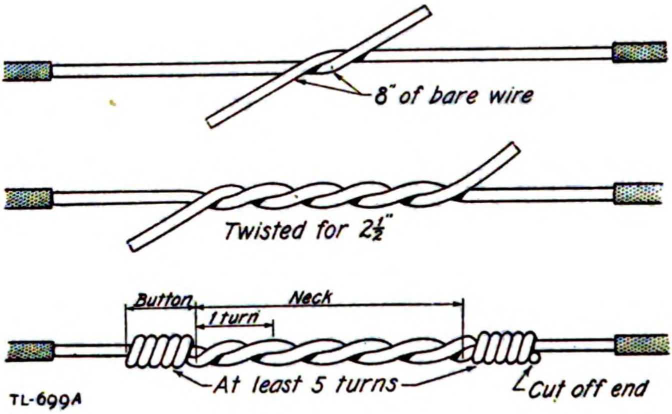


Figure 7

After the splice is completed, the end of the circuit if no longer required, may be cut free. In any case, this splice is seized and taped in the same manner as other field wire splices. The amount of insulation removed from the main wire is about 1½ inches. Make the splice as illustrated in figure 8.

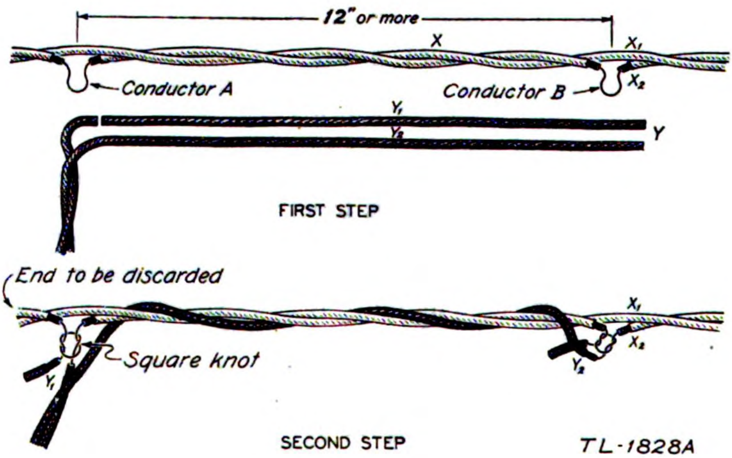


Figure 8

12. Taping the splice.—For best results, the splice should be held taut when applying the tape. Each splice is protected with two reversed layers of rubber tape and friction tape.

Applying the rubber tape: Use a piece about 4 inches long. Start in the center of the splice and wrap toward the right until the ½ inch of rubber insulation has been covered. Reverse the wrap toward the left until ½ inch of rubber insulation is covered then reverse and end wrap in center. The tape must be stretched, the ends of the wrapping should be pressed down tightly to keep the splice waterproof and each turn of the tape should cover half of the one previously applied. See figure 9.

Applying the friction tape: Apply two reversed layers of friction tape over the rubber tape in the same manner except this time extend the wrap to inclose about 1 inch of braid to hold the braid in place. The overall length of the finished

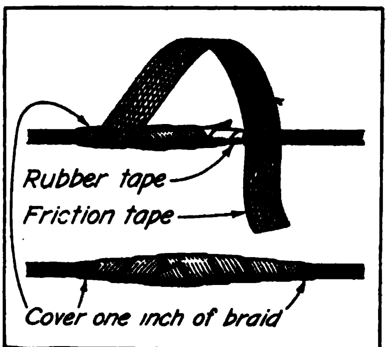


Figure 9a

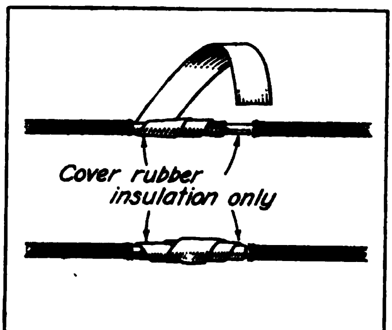


Figure 9b

splice should not exceed 4 inches. Roll the splice several times in the hands to seal the edges of the tape.

Review questions.—

1. Name the three major parts of the electricians knife.

2. How are pliers classified?

3. What is the principal use of the diagonal pliers? Name the largest size steel wire that may be cut with these pliers, the largest size copper.

4. Name two uses of the side-cutting pliers.

5. How much stagger is placed in a field wire splice?

6. What knot is used to make a field wire splice?

7. How much space is left between the knot and the rubber insulation in a field wire splice? How much rubber insulation is exposed?

8. When would a combination seizing wire splice be used?

9. What is used to insulate a field wire splice?

10. Name one important point to be observed when using pliers.

11. Why is it advisable to stagger the splices made in twisted pair wire?

12. What is the tap splice used for?

13. How is solid wire parted when using side-cutting pliers to cut it?

14. What is the amount of stagger used when making a "T" splice?

15. Name three uses of the long-nose pliers.

LESSON 2

LABORATORY

Tools and materials.—

Knife, TL-29
Pliers, side-cutting
Pliers, long-nose
Pliers, diagonal
*Wire W-110
*Wire, bare copper No. 10
*Wire W-38 or W-50
*Seizing wire, 22-gauge bare copper

Items marked * are not placed on the memorandum receipt.

Procedure.—

Operation 1.—Using wire W-110, make a field wire splice.

................................Ins. check

Operation 2.—Using wire W-110 make a "T" or field wire tap splice.

................................Ins. check

Operation 3.—Using number 10 bare copper wire and W-110, make a combination seizing wire splice.

................................Ins. check

Operation 4.—Using wire W-38 or W-50, make a tap splice.

................................Ins. check

Operation 5.—Using wire W-38 or W-50 make a Western Union splice. Submit all splices to instructor for approval.

................................Ins. check

Operation 6.—Following the instructions in the information sheet, tape the splices made under operations 1 and 3.

................................Ins. check

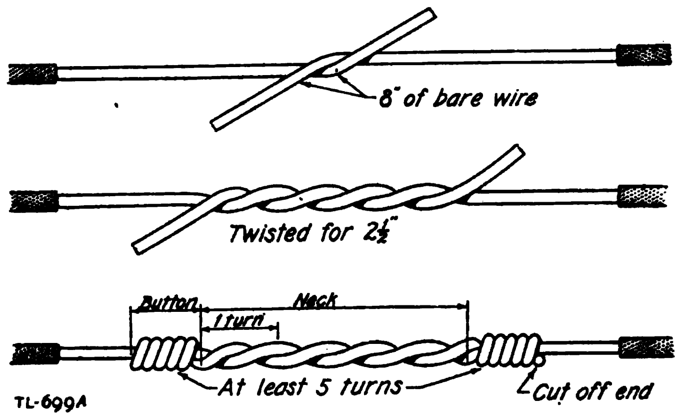


Figure 7

After the splice is completed, the end of the circuit if no longer required, may be cut free. In any case, this splice is seized and taped in the same manner as other field wire splices. The amount of insulation removed from the main wire is about 1½ inches. Make the splice as illustrated in figure 8.

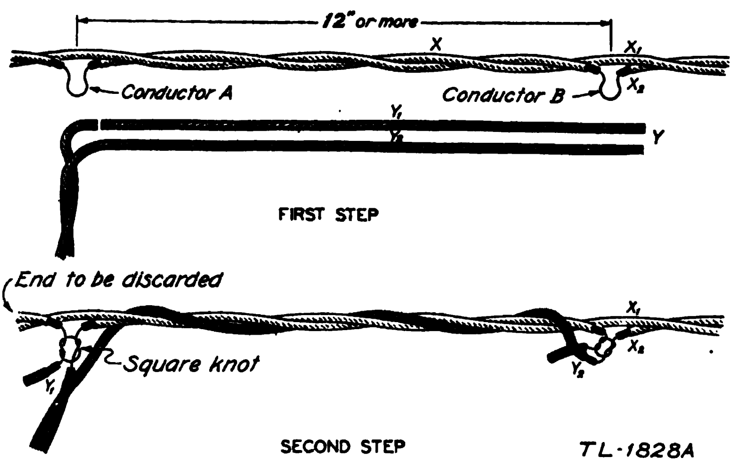


Figure 8

12. Taping the splice.—For best results, the splice should be held taut when applying the tape. Each splice is protected with two reversed layers of rubber tape and friction tape.

Applying the rubber tape: Use a piece about 4 inches long. Start in the center of the splice and wrap toward the right until the ½ inch of rubber insulation has been covered. Reverse the wrap toward the left until ½ inch of rubber insulation is covered then reverse and end wrap in center. The tape must be stretched, the ends of the wrapping should be pressed down tightly to keep the splice waterproof and each turn of the tape should cover half of the one previously applied. See figure 9.

Applying the friction tape: Apply two reversed layers of friction tape over the rubber tape in the same manner except this time extend the wrap to inclose about 1 inch of braid to hold the braid in place. The overall length of the finished

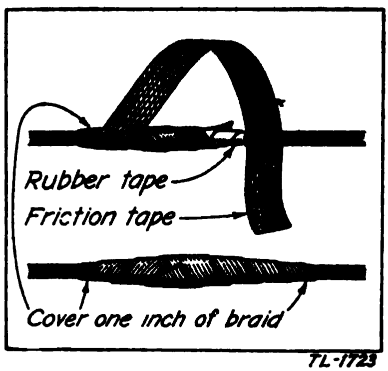


Figure 9a

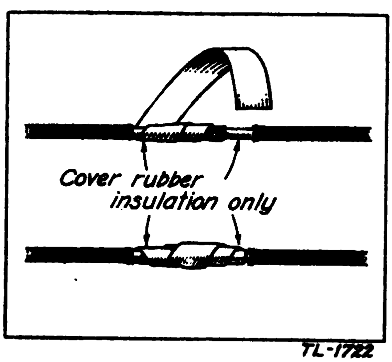


Figure 9b

splice should not exceed 4 inches. Roll the splice several times in the hands to seal the edges of the tape.

Review questions.—

1. Name the three major parts of the electricians knife.

2. How are pliers classified?

3. What is the principal use of the diagonal pliers? Name the largest size steel wire that may be cut with these pliers, the largest size copper.

4. Name two uses of the side-cutting pliers.

5. How much stagger is placed in a field wire splice?

6. What knot is used to make a field wire splice?

7. How much space is left between the knot and the rubber insulation in a field wire splice? How much rubber insulation is exposed?

8. When would a combination seizing wire splice be used?

9. What is used to insulate a field wire splice?

10. Name one important point to be observed when using pliers.

11. Why is it advisable to stagger the splices made in twisted pair wire?

12. What is the tap splice used for?

13. How is solid wire parted when using side-cutting pliers to cut it?

14. What is the amount of stagger used when making a "T" splice?

15. Name three uses of the long-nose pliers.

LESSON 2

LABORATORY

Tools and materials.—

Knife, TL-29
Pliers, side-cutting
Pliers, long-nose
Pliers, diagonal
*Wire W-110
*Wire, bare copper No. 10
*Wire W-38 or W-50
*Seizing wire, 22-gauge bare copper

Items marked * are not placed on the memorandum receipt.

Procedure.—

Operation 1.—Using wire W-110, make a field wire splice.

..............................Ins. check

Operation 2.—Using wire W-110 make a "T" or field wire tap splice.

..............................Ins. check

Operation 3.—Using number 10 bare copper wire and W-110, make a combination seizing wire splice.

..............................Ins. check

Operation 4.—Using wire W-38 or W-50, make a tap splice.

..............................Ins. check

Operation 5.—Using wire W-38 or W-50 make a Western Union splice. Submit all splices to instructor for approval.

..............................Ins. check

Operation 6.—Following the instructions in the information sheet, tape the splices made under operations 1 and 3.

..............................Ins. check

LESSON 3

MEASURING AND GAUGING

1. Steel scale.—The steel scale is a metal ruler with one or more of its edges accurately marked with some fractional part of the inch or meter. The most commonly used scale is *the number 4 graduation.* The edges of this scale are laid out as follows: 1st edge, 8th of an inch; 2d edge, 16ths of an inch; 3d edge, 32ds of an inch; 4th edge, 64ths of an inch.

The steel scale is used for all linear measurements where a high order of accuracy is required, also as a straight edge to determine whether a surface is absolutely flat.

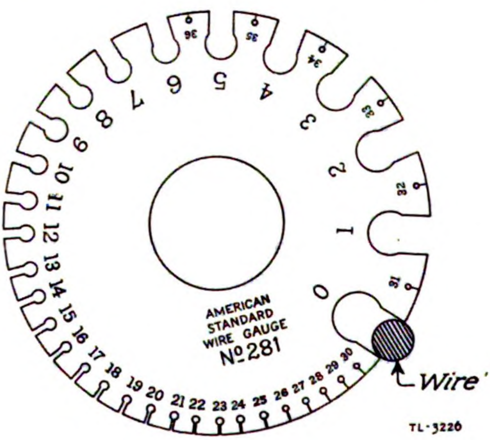


Figure 1

2. Wire gauges.—The wire gauge is a tool used for measuring the diameter of wire. The most common forms of this gauge are, the circular wire gauge and the combination wire and screw gauge. Wire diameters are given in two ways, by a gauge number and in mils. One mil equals 1/1000th of an inch. Examination of the gauges will reveal that the

larger the gauge number, the smaller the diameter of the wire. There are several different standards for wire gauges in the United States (see table I). The wire standards most commonly used are the American or Brown and Sharpe for copper and Birmingham or Stubbs for iron wire. It will be noted that *for any given gauge size the iron wire is few mils larger in diameter than the copper wire.*

The circular wire gauge is used to measure wire as shown in figure 1.

Do not force the wire into a slot. Find the slot that refuses to pass the wire without forcing, then try next larger until one is found that passes the wire. This is the correct size. The combination wire and screw gauge is used in practically the same way, except that the wires are slipped into a "V" shaped opening in the scale. The number that comes the nearest to the center of the wire or screw being measured, gives the correct gauge.

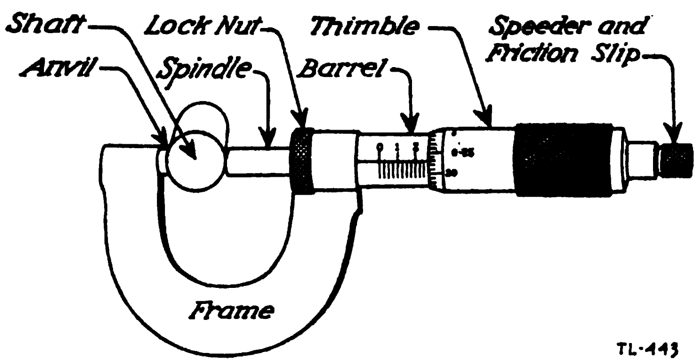


Figure 2

3. The micrometer caliper.—This tool is used to measure the diameters of objects in thousandths of an inch. The illustration given in figure 2 shows the method of measuring and names the major parts of the tool. The micrometer, in conjunction with a table showing wire sizes and diameter in thousandths of inches is frequently used as a wire gauge.

The instructor will demonstrate the use of this tool.

4. Speed indicator.—This tool is used to determine the revolutions per minute (rpm) of motors and shafts revolving either clockwise or counterclockwise. There are several types of this instrument, the one usually encountered in the Signal Corps being the I-16. The instructor will demonstrate its use.

5. Tapes.—Tapes are flexible measuring devices, laid off in fractions of an inch, inches and feet. The most common lengths are the 6 ft. 50 ft and the 100 ft tapes. These tapes are furnished in three grades; the cloth tape of woven cotton or linen, the metallic tape, which is cloth interwoven with metal strands; and the steel tape which is a high grade metal ribbon. The steel tape is the most efficient, being little affected by temperature changes, does not stretch and is very durable. Care should be exercised to keep the steel tape flat when using it since a kink may cause it to break.

6. Thickness gauges.—The thickness gauge is a steel leaf, with its diameter in thousandths of an inch stamped on one surface. This type of gauge is used to measure small air gaps between relay springs, gear teeth, armatures and cores, etc. The correct gauging of a gap is obtained by using a gauge leaf that touches each side of the gap without moving either of the two parts, or, is tight without sideplay or bind. A sensitive touch must be acquired in order to obtain the correct reading of clearances.

Review questions.—

1. Name one use of the steel scale.

2. What is the wire gauge used for?

3. What part of an inch is a mil?

4. Which wire has the greater diameter, No. 10 or No. 22?

5. What is the smallest measurement that can be made with the micrometer caliper?

6. What is the name of the instrument used to count rpm's of shafts and motors.

7. Which is the most accurate tape, metallic or steel?

8. What is the thickness gauge used for?

Note.—In order to determine the area of a given cross section of wire, square the diameter as given in mils. For example, it is desired to know the area in circular mils of the cross section of No. 0000 B&S copper wire. By reference to table I, the diameter is found to be 0.46 inch. This is equal to 460 mils. 460^2 equals 211,600 circular mils, the area of the cross section.

TABLE 1
DIFFERENT STANDARDS FOR WIRE GAUGES IN USE IN THE UNITED STATES

(Dimensions of sizes in decimal parts of an inch)

No. of wire gauge	*American or Brown & Sharpe Co.*	*Birmingham, or Stubs iron wire*	*Washburn & Moen Mfg. Co. or Roebling*	*English legal Standard*	*Stubs steel wire*	*U S Standard gauge for sheet and plate iron and steel*	*No. of wire gauge*
000000	....	....	....	0.464	....	0.46875	000000
00000	....	....	....	.432	....	.4375	00000
0000	0.46	.4540	0.3938	.400	....	.40625	0000
000	.40964	.425	.3625	.372	....	.375	000
00	.3648	.38	.3310	.348	....	.34375	00
0	.32486	.34	.3065	.324	....	.3125	0
1	.2893	.3	.2830	.300	.0227	.28125	1
2	.25763	.284	.2625	.276	.219	.265625	2
3	.22942	.259	.2437	.252	.212	.25	3
4	.20431	.238	.2253	.232	.207	.234375	4
5	.18194	.22	.2070	.212	.204	.21875	5
6	.16202	.203	.1920	.192	.201	.203135	6
7	.14428	.18	.1770	.176	.199	.1875	7
8	.12849	.165	.1620	.160	.197	.171875	8
9	.11443	.148	.1483	.144	.194	.15625	9
10	.10189	.134	.1350	.128	.191	.140625	10
11	.090742	.12	.1205	.116	.188	.125	11
12	.080808	.109	.1055	.104	.185	.109375	12
13	.071961	.095	.0915	.092	.182	.09375	13
14	.064084	.083	.0800	.080	.180	.078125	14
15	.057068	.072	.0720	.072	.178	.0703125	15
16	.05082	.065	.0625	.064	.175	.0625	16

TABLE 1 (continued)
DIFFERENT STANDARDS FOR WIRE GAUGES IN USE IN THE UNITED STATES

(Dimensions of sizes in decimal parts of an inch)

No. of wire gauge	*American or Brown & Sharpe Co.*	*Birming-ham, or Stubs iron wire*	*Washburn & Moen Mfg. Co. or Roebling*	*English legal Standard*	*Stubs steel wire*	*U.S Stand-ard gauge for sheet and plate iron and steel*	*No. of wire gauge*
17	.045257	.058	.0540	.056	.172	.05625	17
18	.040303	.049	.0475	.048	.168	.05	18
19	.03589	.042	.0410	.040	.164	.04375	19
20	.031961	.035	.0348	.036	.161	.0375	20
21	.028462	.032	.03175	.032	.157	.034375	21
22	.025347	.028	.0286	.028	.155	.03125	22
23	.022571	.025	.0258	.024	.153	.028125	23
24	.0201	.022	.0230	.022	.151	.025	24
25	.0179	.02	.0204	.020	.148	.021875	25
26	.01594	.018	.0181	.018	.146	.01875	26
27	.014195	.016	.0173	.0164	.143	.0171875	27
28	.012641	.014	.0162	.0149	.139	.015625	28
29	.011257	.013	.0150	.0136	.134	.0140625	29
30	.010025	.012	.0140	.0124	.127	.0125	30
31	.008928	.01	.0132	.0016	.120	.0109375	31
32	.00795	.009	.0123	.0108	.115	.01015625	32
33	.00708	.008	.0118	.0100	.112	.009375	33
34	.006304	.007	.0104	.0092	.110	.00859375	34
35	.005614	.005	.0095	.0084	.108	.0078125	35
36	.005	.004	.0090	.0076	.106	.00703125	36
37	.004453	....	....	.0068	.103	.006640623	37
38	.003965	....	....	.0060	.101	.00625	38
39	.003531	....	....	.0052	.099	....	39
40	.003144	....	....	.0048	.097	....	40

LESSON 3

LABORATORY

Tools and materials.—

Combination wire and screw gauge
Wire gauge, American standard
Thickness gauge
Steel scale
Speed indicator, I-16
Micrometer caliper
*Wire, screw and plate samples

*Items marked * are not placed on the memorandum receipt.*

Procedure.—

Operation 1.—Examine the steel scale, and record in the space below the different graduations on its edges.

..............................Ins. check

Operation 2.—Use the wire gauges furnished. Measure the wire samples and record the results in the space below. Measure the screw samples, as to length and gauge. Record results in the space below.

	Screws	
Wires	*Length*	*Gauge No.*
1..................	1..................	....
2..................	2..................	....
3..................	3..................	....

..............................Ins. check

Operation 3.—Measure the wire and plate samples with the micrometer caliper. Record the results of the operation below. Compare your measurements with the ones shown on the attached chart. Check the gauge thus determined with those. The instructor will demonstrate the use of this instrument.

	Diameter in mils	*Ga.*		*Thickness in mils*	*Ga.*
	1..................................			1..................................	
Wire	2..................................		Plate	2..................................	
Samples	3..................................		Samples	3..................................	

..............................Ins. check

Operation 4.—Examine the speed indicator. The instructor will demonstrate the use of this instrument. Find the rpm of motor mounted on work bench. Record result below.

..............................Ins. check

Operation 5.—Examine the thickness gauge furnished. Measure the air gaps of one of the sample sets on the bulletin board, and record the results below.

A B C (Underline the set used)

1........................ 2........................

3........................ 4........................

..............................Ins. check

LESSON 4

METAL WORKING

1. **Files.**—A file is a tool used for smoothing and shaping hard materials such as brass, copper, iron bakelite, etc. Files are classified according to length, measured from the shoulder to the point, by shape, and by the cut. There are twelve standard file shapes, the most common being, flat, half round, round, triangular and square. The lengths usually run from 2 to 14 inches.

Cuts of files.—This classification, which pertains to the teeth of a file, has three subdivision, single cut, double cut and rasp, which are illustrated in figure 1.

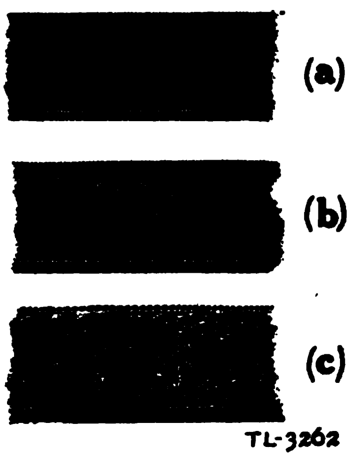


Figure 1

File teeth.—The cut of a file is also classified according to the coarseness of the teeth as rough, coarse, bastard, second cut, smooth and dead smooth. Do not confuse the term "second cut," which applies to the size of the teeth,

with the term "double cut" which refers to the kind of teeth.

Selecting the file.—The proper file to use for any given job depends on a number of factors; the ones listed below are general rules only.

The type of metal, whether cast or wrought. Cast metals are the hardest to cut and a new file should be used if possible.

The shape of the piece to be smoothed. Use a file that will reach all parts of an irregularly shaped piece. As an example, a slitting file would be the correct shape for a diamond shaped opening; an equaling file is the best shape for a narrow slot; a flat file is the best for squaring ends and surfaces.

The area of the surface being dressed. A large surface should be brought to shape with a rough or course file of a large size. Smaller pieces should be shaped with smaller files in either the bastard or second cut grade of teeth.

The degree of accuracy required. The bastard file is the best for general use where the fit tolerance is not so critical and the appearance of the finished work is not important. For close fits and where it is desired to prepare the work for buffing or polishing, the final shaping should be done with the second cut or smooth file. The dead smooth file is seldom used.

A flat file is not exactly flat, but slightly convex on both sides. This concentrates the pressure on a few teeth in the center of the file, reducing the amount of force required to move the tool over the piece. This gives the operator better control over the file.

Hand filing is a difficult job. It requires considerable skill and patience. The beginner will find that the slower he runs the file over the work, the less chance there is of rounding the corners of the piece being squared. Some general rules for the use of the file are given below:

Select the proper shape, size and cut of file.

Always use a file handle; this gives the user the best control of the file.

Apply pressure on the forward stroke only. The teeth are

not supported by the body of the file on the backstroke. Pressure in this direction breaks the teeth and the file soon becomes useless.

Assume a natural position and use as long a stroke as possible.

The work should be held securely, and if in a vice, should be below the line of the workman's elbow.

The file should be held firmly and an effort should be made to apply an equal amount of pressure with each hand.

Keep the file free of cuttings. This is best done with a file card, which is simply a flat wire brush. Copper and tin, also lead to a certain extent, have a tendency to clog the file teeth. This may be reduced by rubbing chalk over the file.

The file needs more care than it normally gets. Keep it free from rust, do not drop it across other tools and do not carry it loose in a tool bag.

2. Hacksaws.—The hacksaw is a metal frame used to hold blades specially made for the cutting of metals and other hard materials. The frame is usually adjustable to accommodate the various lengths of blades. It is equipped with two pin spindles to hold the blades under tension, the one on the handle being equipped with a knurled sleeve. This locks the blade in place after the proper tension has been placed on it, by turning the handle. Examination of the spindles will disclose the fact that they may be moved to various positions in the frame. This permits the blade to be turned at right angles to the frame which is necessary for some classes of work.

There are two grades of hacksaw blades, coarse and fine. The coarse blades are used for general work and the finer blades to cut thin plate, sheet metal, thin walled tubes and small rods. The teeth of the hacksaw blade are given set to prevent the blade from binding in the cut. To insure a straight cut and ease of operation, the following rules should be observed:

Insert the blade with the teeth pointing away from the handle, turn the handle until the blade is tight and run the sleeve down to prevent it from slipping.

Apply pressure on the forward stroke only.

Use a long slow stroke; do not force the cut.

Hold the work securely. Have the cut as close to the point of support as possible.

3. Hand drills.—The hand drill is a tool used for driving twist drills. Hand drills are made with various chuck capacities, the ¼ and ⅜ inch being the ones most commonly used. Some hand drills are equipped with a speed change, ratchets for working in close quarters, and a lock to hold the gear assembly steady while tightening or loosening the chuck. The chuck of the hand drill is of the three jaw type and is designed to hold drills with round shanks only. *The chuck is tightened by hand only.* Do not use a vice or wrench.

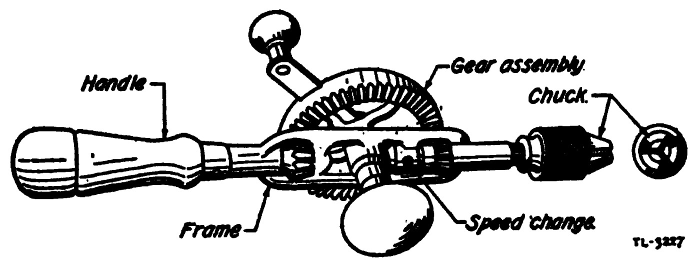


Figure 2

4. Twist drills.—The twist drill is a tool designed to bore holes in practically any material. Small twist drills usually have a round shank for use with the three jaw chuck. There are three classes of drills in common use: the wire gauge series, numbered from 1 to 80; the lettered series A (.243) to Z (.413); and the series that begins at 1/64th of an inch and increases in size by 64ths to ½ inch. The twist drill for general work is made of carbon steel, those used for production work and drilling in the better grades of steel are made of high speed steel.

A twist drill, in order to bore a perfectly round hole, should have both lips ground at the same angle and be of equal length. The angle should be about 60 degrees. Drills should have a lip clearance of 10 to 15 degrees to insure the lip biting the material without interference. See figure 3.

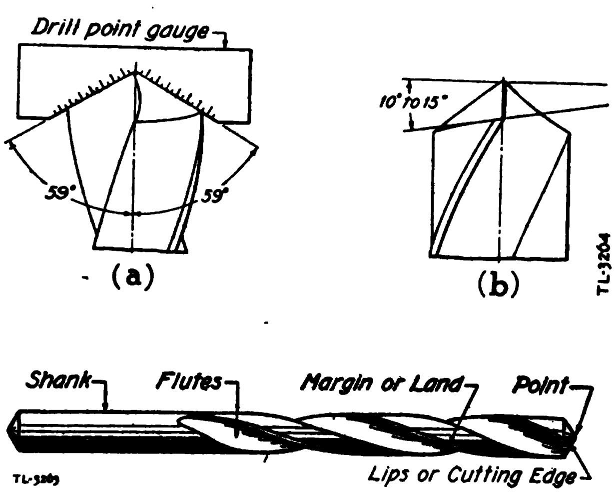


Figure 3

The important points to be remembered when drilling are: the speed with which the drill is turned and the rate at which the drill is fed into the material. A good general rule to follow is, the harder the material the slower the speed and the lighter the feed. This does not apply to bakelite and similar thermo (heat) setting materials. These materials, although they are comparatively soft, clog the drill and heat rapidly unless a slow feed and speed is used. A lubricant, such as lard oil, turpentine or castor oil, should be used to preserve the temper of twist drills. Never use a mineral oil for a cutting oil.

5. Center punch.—The center punch is a steel rod (usually knurled), with one end tapered to a 60 degree tempered point. It is used to dent material prior to drilling. The dent acts as a guide for the point of the drill. This prevents the drill from wandering or taking hold at a place other than the center of the proposed hole. It is not necessary to strike a center punch hard. Tilt the top of the punch to one side, place the point at the site of the proposed hole, raise the punch to the vertical and strike the top *once* with a light hammer.

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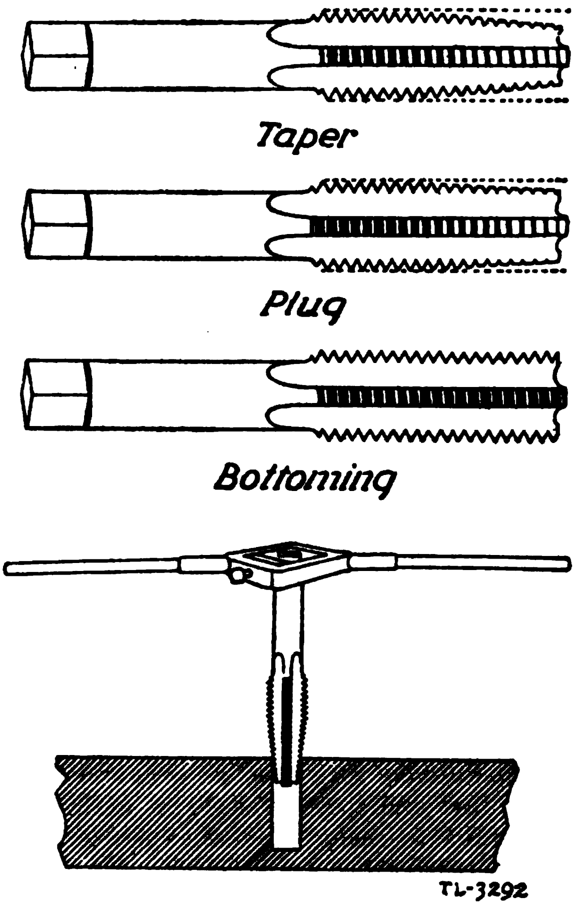


Figure 4

6. Taps and dies.—The tap is a hard steel tool used to cut internal threads. The three kinds of taps are: the taper tap, used where the tap can be run completely thru the hole; the plug tap, used where it is desired to thread a hole which does not run thru the stock; and the bottoming tap, which is used to thread the full depth of the hole. Taps are highly tempered and therefore very brittle. Great care to avoid lateral stresses must be exercised to prevent breaking the tap. A tap broken off in the hole, particularly if broken

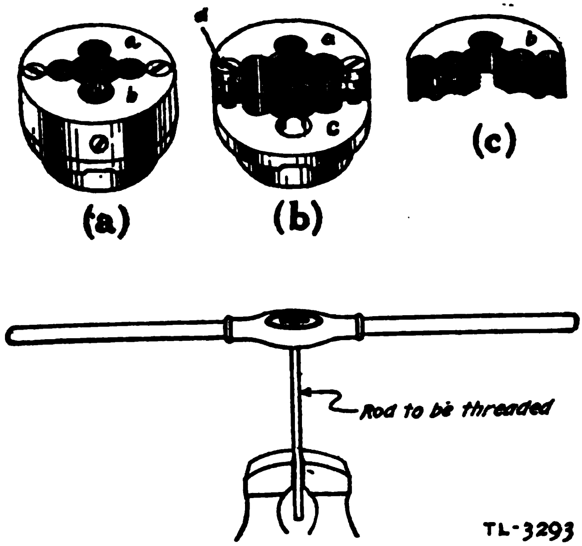


Figure 5

flush with the surface, causes a great deal of extra work. In using the tap, see that it starts straight; this can be checked with the square. After it is started, check it again and if the tap is running slightly crooked, make the attempt to straighten it while turning and not when the tap is standing still. Turn the tap several revolutions to the right and then to the left about a half turn. This prevents the tap from binding, which might cause it to break. In tapping thin brass and bakelite, no lubrication is necessary; for heavy or hard materials, the same lubricants as used for drilling are satisfactory. The tap is held in a special tool called a tap wrench. See figure 4.

The die is a tool used to cut outside threads. It consists of a screwplate, two adjusting screws and a set of thread cutters. The screwplate has a hole in its center which is the size of the outside threads and acts as a guide. The cutters are tapered so that the cut is made gradually, in the same manner as the tap. The threading operation must always be started from the screwplate side. Wear on the cutters may be compensated for, within a small limit, by use of the adjusting screws. A lubricant should be used in the same

manner as specified for taps. The die is held in a special tool called a stock. See figure 5.

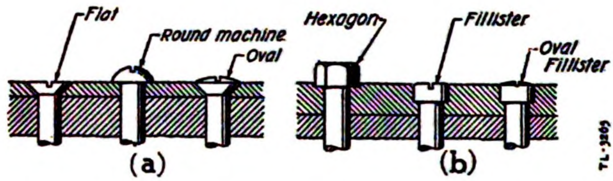


Figure 6

7. Abrasives.—There are a great many tools and materials used to smooth and polish metals, plastics, bakelite or other hard substances. Emery cloth, which consists of powdered emery, glued to a strong cloth, is the abrasive most used to remove tool marks and polish hard metals such as iron and steel. The grades in common use are 000 to No. 2. The emery cloth graded by zeros is considered fine; the greater the number of zeros, the finer the cloth. That graded in whole numbers is considered coarse; the larger the number the coarser the cloth. In the finer polishing operations, lard oil used with emery cloth, produces an excellent finish. A still finer finish is procured if flour is used. *Never use emery or carborundum on soft metals such as copper and brass.* The particles of abrasive will break off and imbed in soft metals and cannot be removed.

Crocus cloth is a heavy cloth faced with jewelers' rouge. It is primarily an abrasive for soft metals, but is useful as a finisher for hard metals. Another use for crocus cloth is the brightening of a commutator of a motor where the least possible amount of material should be removed without danger of leaving abrasives on moving parts.

8. Scribers.—The scriber is a tool used to layoff lines on any hard material. It is simply a metal rod with a sharp point on one end and may be anything from a commercial article to a nail with the point ground down so that it will make a fine line. The top of the scriber should be tilted away from the square or scale when scribing a line, in order that the dimension laid off will be as accurate as possible.

9. Machine screws.—Machine screws are used to hold metal or other hard material parts together. They are classified in the following manner: length, type of head, number of threads per inch, diameter of gauge and the material made of. The common types of machine screw heads are illustrated in figure 6.

10. Nuts.—A nut is a piece of metal having a threaded hole through its center and designed to screw on to the threaded portion of a bolt or machine screw. Nuts are classified according to their shape as square, hexagonal, etc. Nuts are also classified according to the screw or bolt which they are intended to fit. For machine screws, nuts are ordered by specifying the material, shape, the gauge of the diameter and the number of threads per inch, as nuts, hexagonal brass 6-32.

11. The countersink.—On all flat-head machine screws, the angle of the under side of the head is 82 degrees. Therefore, when a flat head screw is used, the hole in which it fits must be countersunk at the surface of the hole where the the head of the screw fits. This allows a screw to be used in a place where the surface of the work must remain flat. The tool which makes this 82 degree hole is called a countersink. They are made of steel and have a round or sqare shank. The point is cut to a taper of 82 degrees. The cutting edges are usually three or four in number. The flutes which lead to the cutting edges are 60 degree, concave, angular grooves. The back rake of the cutting edges are approximately 15 degrees. This is a good angle for most metals. The flutes of a countersink are not cut back full length of the body as in the case of a twist drill because a countersink never is used deeper than about 3/8 inches.

Another type of metal countersink is used when a nut is to be sunk below the surface. This small type of tool has the same kind of cutting edges, but instead of a point, a small pin is set into the end of the tool; also, the angle of the cutters is a right angle to the axis of the tool. This tool must be used with a given size hole which fits the pin of the countersink. This type is made in various sizes and pin

diameters. Various types of countersinks are illustrated in figure 7.

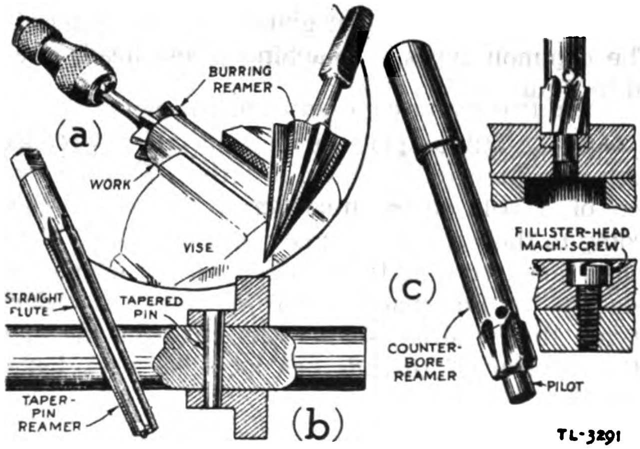


Figure 7

The countersink is usually used in a hand drill provided it has a round shank. If it is equipped with a square shank it must be used in a brace.

Review questions.—

1. What is a file used for?

2. Name two cuts of files according to the coarseness of the teeth.

3. What is used to clean the teeth of a file?

4. Which way should the teeth of a hacksaw point?

5. What important point should be remembered when using the hacksaw?

6. How are files classified?

7. Name two important points to be remembered when using the twist drill.

8. Name one solution used as a cutting oil.

9. What tool is used to mark the center of a hole prior to drilling?

10. Name the three kinds of taps.

11. What tool is used to cut outside threads?

12. Name two materials used to polish metals.

13. Give the five classifications of machine screws.

14. What is the scriber used for?

LESSON 4

LABORATORY

Tools and materials.—

Files, assorted (3)
Hacksaw frame
Hacksaw blades, fine and coarse
Try or combination square
Hand drill
Twist drill No. 35
Twist drill No. 17
Hammer, ball peen
Center punch
Tap and die set, AA-4
File card
*Brass stock, ½x1 inch
*Iron stock, ½x1 inch
*Sheet brass
*Iron plate
*Bakelite
*¼-inch brass rod.

Items marked * are not placed on the memorandum receipt.

Procedure.—

Operation 1.—Using the ½-inch x 1-inch brass stock, cut, square the ends with the files, lay out the holes, drill and tap the following figure. Refer to figure 4 before using taps.

..............................Ins. check

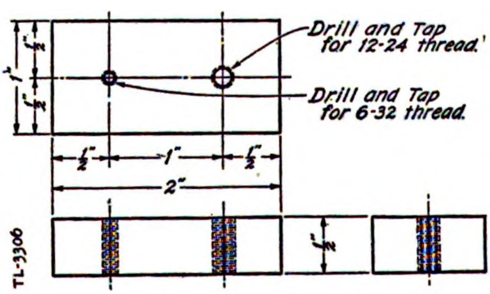


Figure 8

Operation 2.—Cut a piece of the iron stock furnished, 1½ inches long. Square the ends with the files.

..............................Ins. check

Operation 3.—Cut a piece of sheet brass using figure 9(a) for dimensions. Square the piece, layout the holes, drill and tap as shown.

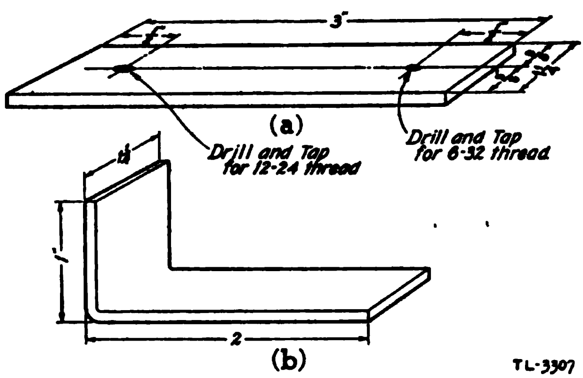


Figure 9

After this piece has been checked by the instructor, cut it into two pieces 1¼ inches by 1½ inches. Save these pieces as they are to be used in a later lesson.

..............................Ins. check

Operation 4.—Cut a piece of the iron plate and square it. Make the bracket shown in figure 9(b).

..............................Ins. check

Operation 5.—Cut a piece of bakelite 1 inch by 2½ inches. Square the piece. Use the emery cloth furnished and smooth the surfaces.

..............................Ins. check

Operation 6.—Use the brass rod furnished. Cut 1 inch of threads on one end only.

..............................Ins. check

ANNEX LESSON FOUR

BASIC THREAD DIMENSIONS, TAP AND CLEARANCE DRILL SIZES

Machine Screw Sizes—National Form

Nominal Sise	*Major Diameter*	*Tap Drill Number*	*Clearance Drill Number*	*Decimal Equivalent of Tap Drill*	*Decimal Equivalent of Clearance Drill*
0-80	.0600	56	48	.0469	.0760
1-56	.0730	54	45	.0550	.0820
-64	.0730	53	45	.0595	.0820
-72	.0730	53	45	.0595	.0820
2-56	.0860	50	42	.0700	.0930
-64	.0860	50	42	.0700	.0930
3-48	.0990	47	37	.0785	.1040
-56	.0990	45	38	.0820	.1040
4-32	.1120	45	32	.0820	.1160
-36	.1120	44	31	.0860	.1200
-40	.1120	43	31	.0890	.1200
-48	.1120	42	30	.0935	.1280
5-36	.1250	40	30	.0980	.1280
-40	.1250	38	29	.1015	.1360
-44	.1250	37	29	.1040	.1360
6-32	.1380	35	28	.1100	.1400
-36	.1380	34	28	.1110	.1400
-40	.1380	33	28	.1130	.1400
7-30	.1510	31	22	.1200	.1570
-32	.1510	31	22	.1200	.1570
-36	.1510	30	22	.1280	.1570
8-30	.1640	30	18	.1285	.1690
-32	.1640	29	18	.1360	.1690
-36	.1640	29	18	.1360	.1690
-40	.1640	28	18	.1405	.1690
9-24	.1770	29	13	.1360	.1850
-30	.1770	27	13	.1440	.1850
-32	.1770	26	13	.1470	.1850
10-24	.1900	25	9	.1495	.1960
-28	.1900	23	9	.1540	.1960
-30	.1900	22	9	.1570	.1960
-32	.1900	21	9	.1590	.1960

Machine Screw Sizes—National Form (continued)

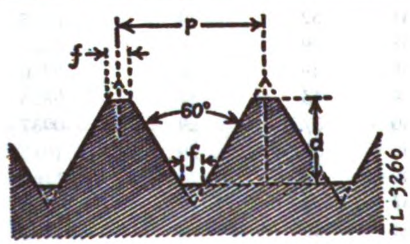
Nominal Size	*Major Diameter*	*Tap Drill Number*	*Clearance Drill Number*	*Decimal Equivalent of Tap Drill*	*Decimal Equivalent of Clearance Drill*
12-24	.2160	16	1	.1770	.2280
-28	.2160	14	1	.1820	.2280
-32	.2160	13	1	.1850	.2280
14-20	.2420	10	1/4	.1935	.2500
-24	.2420	7	1/4	.2010	.2500
16-18	.2680	3	9/32	.2130	.2810
-20	.2680	3	9/32	.2130	.2810
-22	.2680	2	9/32	.2130	.2810

Fractional Sizes—National Form

Nominal Size	*Major Diameter*	*Tap Drill Number*	*Clearance Drill Number*	*Decimal Equivalent of Tap Drill*	*Decimal Equivalent of Clearance Drill*
1/16-64	.0625	3/64	50	.0469	.0700
-72	.0625	3/64	50	.0469	.0700
5/64-60	.0781	1/16	44	.0625	.0860
-72	.0781	52	44	.0635	.0860
3/32-48	.0938	49	38	.0730	.1010
-50	.0938	49	38	.0730	.1010
7/64-48	.1094	43	31	.0890	.1200
1/8-32	.1250	3/32	29	.0937	.1360
-40	.1250	38	29	.1015	.1360
9/64-40	.1406	32	25	.1160	.1490
5/32-32	.1563	1/8	19	.1250	.1660
-36	.1563	30	19	.1285	.1660
11/64-32	.1719	9/64	14	.1408	.1820
3/16-24	.1875	26	9	.1470	.1960
-32	.1875	22	9	.1570	.1960
13/64-24	.2031	20	3	.1610	.2190
7/32-24	.2188	16	1	.1770	.2280
-32	.2188	12	1	.1890	.2280
15/64-24	.2344	10	1/4	.1935	.2500

Fractional Sizes—National Form (continued)

Nominal Size	*Major Diameter*	*Tap Drill Number*	*Clearance Drill Number*	*Decimal Equivalent of Tap Drill*	*Decimal Equivalent of Clearance Drill*
1/4-20	.2500	7	17/64	.2010	.2650
-24	.2500	4	17/64	.2090	.2650
5/16-18	.3125	17/64	21/64	.2656	.3281
-24	.3125	9/32	21/64	.2812	.3281
-32	.3125	19/64	21/64	.2968	.3281
3/8-16	.3750	5/16	25/64	.3125	.3906
-20	.3750	21/64	25/64	.3281	.3906
-24	.3750	21/64	25/64	.3281	.3906
7/16-14	.4375	3/8	29/64	.3750	.4531
-20	.4375	25/64	29/64	.3906	.4531
-24	.4375	25/64	29/64	.3906	.4531
1/2-12	.5000	27/64	33/64	.4218	.5156
-20	.5000	29/64	33/64	.4531	.5156
-24	.5000	29/64	33/64	.4531	.5156
9/16-12	.5625	31/64	37/64	.4843	.5781
-18	.5625	33/64	37/64	.5156	.5781
5/8-11	.6250	17/32	41/64	.5312	.6406
-12	.6250	35/64	41/64	.5468	.6406
-18	.6250	37/64	41/64	.5781	.6406
11/16-11	.6875	19/32	45/64	.5937	.7031
-16	.6875	5/8	45/64	.6250	.7031
3/4-10	.7500	21/32	49/64	.6562	.7656
-12	.7500	43/64	49/64	.6781	.7656



p = pitch
d = depth
f = flat

Formula:

$$p = 1/\text{No. thds. per in.}$$
$$d = p \times .64952$$
$$f = p/8$$

Figure 10

DECIMAL EQUIVALENT OF DRILLS NO. 1 TO 60

Drill No.	*Decimal*	*Drill No.*	*Decimal*
1	.228	31	.120
2	.221	32	.116
3	.213	33	.113
4	.209	34	.111
5	.205	35	.110
6	.204	36	.106
7	.201	37	.104
8	.199	38	.101
9	.196	39	.099
10	.193	40	.098
11	.191	41	.096
12	.189	42	.093
13	.185	43	.089
14	.182	44	.086
15	.180	45	.082
16	.177	46	.081
17	.173	47	.078
18	.169	48	.076
19	.166	49	.073
20	.161	50	.070
21	.159	51	.067
22	.157	52	.063
23	.154	53	.059
24	.152	54	.055
25	.149	55	.052
26	.147	56	.046
27	.144	57	.043
28	.140	58	.042
29	.136	59	.041
30	.128	60	.040

DECIMAL EQUIVALENT OF FRACTIONAL DRILLS 1/64 TO 1 INCH

Drill Size	*Decimal*	*Drill Size*	*Decimal*
1/64	.0156	33/64	.5156
1/32	.0312	17/32	.5312
3/64	.0468	35/64	.5468
1/16	.0625	9/16	.5625
5/64	.0781	37/64	.5781
3/32	.0937	19/32	.5937
7/64	.1093	39/64	.6093
1/8	.1250	5/8	.6250
9/64	.1406	41/64	.6406

DECIMAL EQUIVALENT OF FRACTIONAL DRILLS 1/64 TO 1 INCH (continued)

Drill Size	*Decimal*	*Drill Size*	*Decimal*
5/32	.1562	21/32	.6562
11/64	.1718	43/64	.6718
3/16	.1875	11/16	.6875
13/64	.2031	45/64	.7031
7/32	.2187	23/32	.7187
15/64	.2343	47/64	.7343
1/4	.2500	3/4	.7500
17/64	.2656	49/64	.7656
9/32	.2812	25/32	.7812
19/64	.2968	51/64	.7968
5/16	.3125	13/16	.8125
21/64	.3281	53/64	.8281
11/32	.3437	27/32	.8437
23/64	.3593	55/64	.8593
3/8	.3750	7/8	.8750
25/64	.3906	57/64	.8906
13/32	.4062	29/32	.9062
27/64	.4218	59/64	.9218
7/16	.4375	15/16	.9375
29/64	.4531	61/64	.9531
15/32	.4687	31/32	.9687
31/64	.4843	63/64	.9843
1/2	.5000	1	1.0000

LESSON 5

SOLDERING

1. **General.**—Soldering is the binding together of two or more metals by means of a fusible alloy of tin and lead called solder. The solder used in the operation must melt at a lower temperature than the metals being joined together. However, the nearer the melting points of the solder and the soldered metals, the stronger the completed joint.

2. **Fluxes.**—When a metal is heated, its surface combines with the oxygen of the air, forming a substance called oxide. A flux is used to prevent this oxide from forming when soldering. If a flux were not used, it would be impossible to solder a joint. Rust on a piece of iron is a kind of oxide.

There are two classes of fluxes, *corrosive* and *noncorrosive*. A corrosive flux is used when soldering galvanized iron, zinc, iron and steel. Borax, sal ammoniac and zinc chloride are corrosive fluxes. A corrosive flux should seldom be used in electrical work, as it eats away the metal being soldered. After using a corrosive flux, the joint must be thoroughly cleaned to remove traces of the flux that are left on it, thus preventing the flux from eating away any more of the material. Stearine, rosin, and tallow are noncorrosive fluxes. These are used when soldering copper, lead, tin, etc. A noncorrosive flux prevents and cleans the oxide, when soldering, without eating away any of the material. Rosin is the most common noncorrosive flux. It may be in the form of a powder, a liquid, or a paste.

A flux, to have a cleansing effect on a surface, must melt at or below the fusing point of the solder and must prevent any oxidation by excluding the air during the process of soldering. Different substances solder better with different

fluxes, although rosin is the best all-around flux for general use. The usual fluxes for common metals are as follows:

Noncorrosive

Aluminum	Stearine
Brass	Rosin
Copper	Rosin
Lead	Rosin, tallow, or Stearine
Tin	Rosin

Corrosive

Iron or steel	Borax or sal ammoniac
Zinc	Zinc chloride
Galvanized iron	Zinc chloride

3. Solder.—Solders are divided into two general classes, hard and soft. Hard solders are usually used in brazing. They are composed of silver and its alloys or other compositions of the harder metals, and have a high melting point. Soft solders are used for general soldering and electrical work. They are composed of lead and tin. The types of soft solders usually encountered in the Signal Corps are; a bar composed of 50 parts tin and 50 parts lead used for general soldering work; and a wire solder with a rosin core, which is very convenient to use when soldering small terminals, lugs, radio or telephone parts.

4. Soldering irons.—The heat for soldering is generally supplied by a soldering copper, commonly called soldering iron. The soldering iron consists of a copper bit fitted with a suitable shank and handle. The bit of the soldering iron is made of copper, because copper has a high thermal conductivity and readily permits the heat to flow from the body of the copper to its tip. In addition, copper tins readily. Different size coppers are used for different kinds of work and are classified according to their weight.

Soldering irons are heated by one of two methods, *externally* or *internally*. The externally heated iron is heated by a gasoline blow torch or a gasoline furnace. The internally

heated, or electric iron, is heated by an electric heating element in the shank of the iron. The electric iron has two great advantages over the torch heated iron. First, it is easier to keep hot while in use. Second, it is easier to keep from overheating. Overheating an iron oxidizes the tinned surface, thus preventing the even flow of solder over the copper surface. Overheating also causes the copper to become rough and pitted. To solder efficiently, the point of the soldering copper must be clean. To free the iron of tarnish and oxide, the point is covered with a thin coat of solder. This process is called tinning. The tinning is usually done on a soft brick, with a part of the top hollowed out. To tin the iron, proceed as follows:

Place a small amount of powdered rosin on one end of the brick and some scrap solder on the other end. Heat the iron with the blow torch.

File one side of the iron, immediately turn it over and rub the filed side first in the rosin and then in the solder. Wipe the excess solder from the point with a clean rag.

Continue filing and tinning each side in succession until all four sides are tinned.

The iron must not be too hot for the best results. If it is too hot, the solder will not stick. To prevent the destruction of the tinning, when heating the iron for use, keep the point of the soldering iron from direct contact with an open flame.

The electric iron is tinned on one side only. File the side selected after the iron is hot and melt a small amount of rosin core solder on the cleaned surface. Wipe off the excess solder with a clean rag.

Usually the irons are made with a removable tip. It is very important that the tip be removed from the element and that both tip and tip socket are cleaned of all scale. This *must* be done after every *thirty hours of operation*. This cleaning is done to prevent the tip from sticking in the element.

If it becomes necessary to remove the element from the iron, the following procedure should be followed:

Remove the tip.

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Hold the element end of the iron in the left hand and unscrew the handle with the right hand.

Slide the handle back on the cord.

Remove the two screws that hold the flat wires which lead to the element.

Remove the element lock nut.

Slide the element case forward and off the element.

Remove the element by sliding it forward.

When renewing the cord of the iron, do not use any wire other than *heater cord,* that is, a cord which has a covering of asbestos on each wire.

5. The blowtorch.—The gasoline blowtorch consists of a round brass tank, an air pump and a burner assembly. The tank is filled with gasoline through a filler plug in the bottom of the tank. On top of the tank near the handle is the air pump which keeps the fuel under pressure; also on top and near the edge of the tank is the threaded vent for the fuel supply tube. The fuel supply tube contains a wick and also supports the burner assembly. The burner assembly consists of a gas orifice, a needle control valve, a vaporizing chamber and a perforated combustion chamber. Just beneath the burner assembly is a priming cup. The procedure in placing the torch in operation is as follows:

Invert the torch and remove the filler plug. *Use drift pin.*

Fill the tank three-fourths full with ordinary gasoline. Do not use high test gasoline and do not fill the tank completely full, because some space must be left for air pressure.

Replace the filler plug and place the torch in an upright position. In replacing the filler plug do not use excessive force. A little soap on the threads of the plug will help seal the container.

Place the fuel under pressure with the air pump. Pump until it works hard.

Hold palm of hand over the end of the combustion chamber and open the needle valve slightly. This allows the fuel to flow into the priming cup. Shut the needle valve when the cup is ¾ full.

Light the gasoline in the priming cup and keep the flame directed toward the combustion chamber.

Just before the fuel is completely burned out of the cup open the needle valve. If the gas does not ignite hold a match near the vent holes in the combustion chamber. Do not hold the match at the end of the chamber.

To increase the flame increase the pressure in the tank and adjust the needle valve. Avoid excessive pressure, because the flame cannot be controlled so well.

The purpose of burning fuel in the priming cup is to thoroughly heat the vaporizing chamber. This causes the liquid fuel to be turned into gas.

When using the torch to heat an iron do not let the point come in direct contact with the flame. To do so will necessitate retinning the point. A blow torch is seldom cared for properly. This results in a great deal of unnecessary repair work. Some general rules for the care of the torch are given below:

After the priming cup has been filled, wipe any spilled gasoline from the other parts of the torch before lighting it.

When the gasoline is nearly consumed in the priming cup, do not open the needle valve fast. If the torch is not hot enough, this will cause a stream of flaming gas to leave the combustion chamber, and create a fire or burn the user seriously.

As the gasoline in the torch is consumed, more air is required. Pump the torch up occasionally.

Metal contracts and expands with changes of temperature. When closing the needle valve, shut it down tight enough to put out the flame and then turn it back a little to prevent freezing.

6. Requirements for good soldering.—In order to do good soldering, it is necessary that the following be observed:

The surface to be joined should be clean, it being impossible to make solder stick to a dirty or greasy surface.

The soldering iron should be cleaned and properly tinned.

The metals being soldered must be heated in order that the solder will adhere to the surface.

The surfaces being joined should be as close together as possible, with the least amount of solder between the surfaces. Too much solder means a poor joint.

The area of the joint being soldered should always be comparatively large to secure the necessary strength. With a properly tinned iron and the proper flux, the success of any soldering operation depends upon the cleansing of the surfaces to be joined and the heat applied to the joint during the soldering operation. The heat which is applied depends upon the speed with which the iron is drawn along the joint. If the iron is moved too slowly, the solder tends to spread too much and if moved too rapidly, the solder will not have time to melt completely and the joint will not be filled with solder. If heavy material is being soldered, the iron will have to be moved more slowly than if the metals being joined are metals whose melting point approaches that of solder. When using an extremely heated iron, the position of the iron is varied as the work progresses. When starting, the point of the iron is used. As the iron cools, it is lowered so that more of the flat tinned surface of the point is in contact with the work. This is not so important with electric irons, as the heat does not vary so greatly if properly used.

7. Soldering splices.—Half and half solder has an electrical conductivity of about one-seventh that of copper. All splices between conductors that are to carry current should have the smallest possible amount of solder separating conductors. This means that the wires to be joined must be as close together as possible before the solder is applied.

There are two methods of soldering a splice. The first, known as flowing, is to hold the hot iron on the top side of the splice and run the solder into the joint. The second, known as sweating, is to heat the joint from the under side while the flux and the solder are applied from the upper side. The wires melt the solder as soon as they become hot enough, and the melted solder is drawn into the cracks between the wires. Sweating is the better method. When

soldering a Western Union splice, it is soldered only in the neck and not in the buttons.

8. Soldering flat surfaces.—When soldering two flat surfaces, such as two overlapping plates of metal, it is usually desirable to tack the two pieces together at several points by drops of solder, before attempting to solder the entire length of the seam. This will hold the two plates in position while the main soldering is being done. When soldering one flat piece of metal to another, they are usually sweated because of the difficulty in getting solder into the joint. If the surfaces to be joined are first tinned, then placed in contact with each other and heated, there is more chance that a better joint will result, than if the solder is drawn into the joint. To sweat such joints, the metals must be close together after being tinned. If the surfaces are uneven, the sweating process is not successful unless it is combined with soldering in the ordinary manner. That is, the surfaces are first tinned, placed in contact, and while being sweated. solder is applied to the edge of the seam and drawn into the joint.

9. Using the electric iron.—The electric soldering iron is delicate in construction and requires careful handling. When soldering, do not swing or jerk the iron to remove excessive solder. This practice endangers men working nearby and may damage adjacent equipment. Do not strike the iron against a solid substance as this is likely to crack the heating element and cause a breakdown of the insulation. When the iron is not in use, always keep it in its holder.

10. Soldering large terminals.—Wiring that terminates at power boards and other apparatus is generally sweated into terminal lugs.

Terminal lugs, especially for the larger sizes of wire, usually have a cup socket at the bottom. When soldering a solid or stranded wire into the socket, the preferable method is to tin the end of the wire and fill the socket with solder; ordinary methods, where the wire is placed in the socket and the solder heated and run into the socket with the iron, make it difficult to get the solder down in the plug. The socket is then heated in the flame of the torch in the case of

large sockets, or with the iron for small sockets. When the solder in the socket is hot, the tinned end of the wire is inserted into the socket and the source of heat removed. The wire should not be moved while the solder is cooling. After the solder has set more solder may be worked in if the socket is not full.

11. Soldering small terminals.—Small terminals are more easily soldered with an electric iron. When soldering wires to terminals, which are mounted near a sealing compound, such as transformers, only enough heat should be applied to melt the solder. Otherwise, the sealing compound will melt and run over the work; but be sure to apply sufficient heat. Only a small amount of solder is necessary on small terminal lugs to make the required joint. The use of too much solder makes a messy and lumpy looking job. An improper joint, one which will probably cause trouble, is where the solder has sweated only to the wire, while between the wire and the lug there is a flux which acts as an insulator. A connection of this kind is due to one of the following causes: A cold soldering iron; the soldering iron held on the work an insufficient length of time; improper use of the iron; and untinned or unclean lugs and wire. The iron should be held on the lug and wire until both become hot enough to melt the solder. This is one of the fundamental rules of good soldering. A satisfactory job cannot be done if the solder is run on a cold or improperly cleaned lug, even though the iron is sufficiently hot and properly tinned.

Terminals and terminal punchings encountered in the telephone work are usually small ones and are of various shapes and sizes. The word "punching" means, that the kind of terminal is punched from a sheet of metal. Punched terminals are usually small and flat, though sometimes they have been shaped to give clearance and accessibility. Other terminals of a similar size are actually the ends of the contact springs of relays, lamps and jack strips, keys and switches of various types. Terminal punchings must have a mounting to hold them in place. Some are mounted separately, or in groups of two or three, by means of screws or merely stuck into the wood frame of an instrument, telephone or

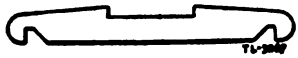

Figure 1

switchboard. The greatest number are mounted in terminal blocks. Standard terminal blocks are assembled to accommodate twenty circuits, having from two to six rows of terminals with twenty terminals in each row, depending upon the purpose they are to serve. The employment of these blocks on main and intermediate distributing frames is covered in another course. A single terminal punching and the end view of the block in which this kind of punching is mounted is shown in figure 1.

An end view of a horizontally mounted terminal block is shown in figure 2.

Note 1.—When blocks are mounted vertically switchboard cable wires are brought in on the left side and under their respective terminals.

Note 2.—Wires are skinned, and scraped of enamel, so that the insulation comes up to but not in the notch or hole of a notched or drilled terminal.

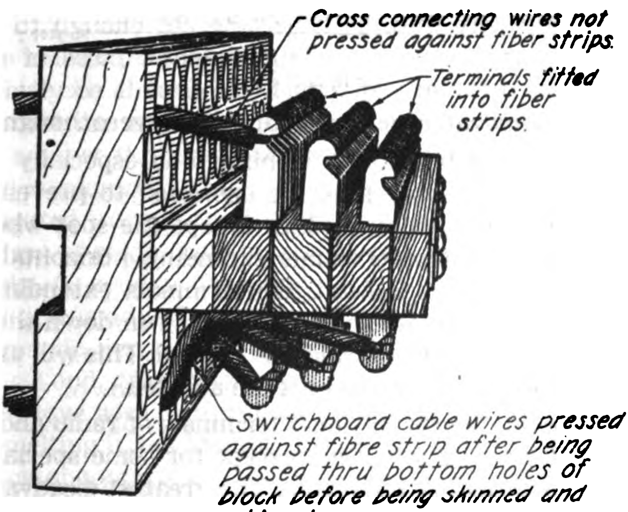

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Figure 2

Types of improperly soldered connections are shown in figure 3.

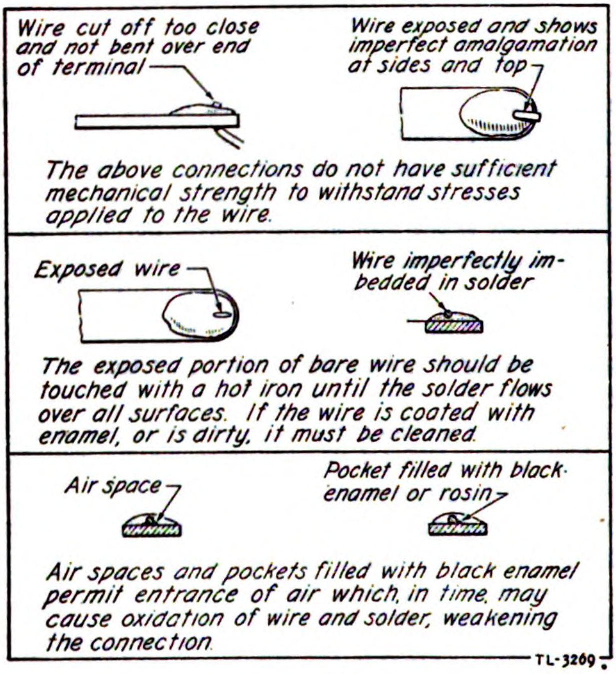

Figure 3

Figure 4 illustrates places to apply solder on terminals.

When soldering terminal punchings and especially those of terminal blocks, care must be exercised to prevent the solder from running to any place except the spot where it should be applied. On terminals extending horizontally or downward this is not difficult. On terminals extending upward it is almost certain that solder will run down the side of the terminal if too much solder is applied. This will usually result in circuit troubles and must be avoided.

The process of soldering small terminals of radio and telephone equipment by sweating, except for some special reason, is not practical or necessary. The greatest disadvantage to its use is that sweating is too slow. The second objection being that it requires more heat to sweat the joint. This

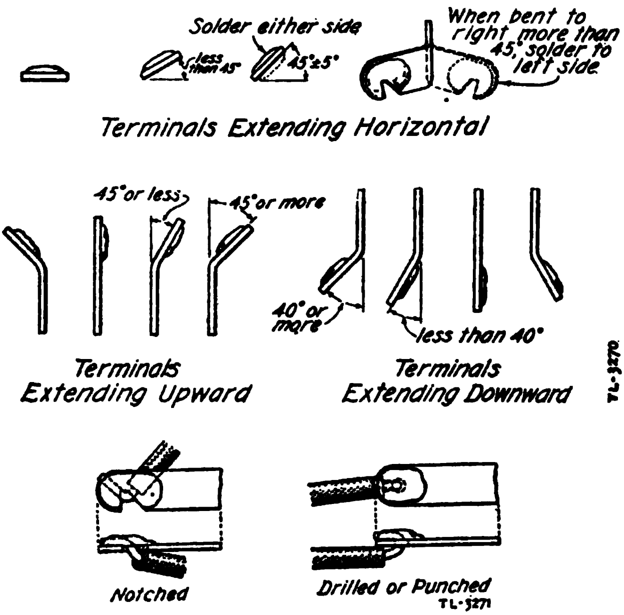

Figure 4

added heat will sometimes cause the compound or fibre in which the terminals are set to melt and loosen the terminal.

The amount of solder usually required for small terminals can easily be obtained by laying the end of a piece of rosin core solder on the terminal so that the length of the solder lying against the terminal extends over the spot where the solder is required. Then place the tip of a properly tinned and heated iron on the solder. As soon as the solder melts, the piece of solder held in the hand is moved away from the iron tip. As soon as the solder on the terminal is completely liquid and is adhering to the wire and terminal as it did to the iron tip, remove the iron by dragging it off toward the terminal end. Allow the soldered joint to cool before attempting to move wire or terminal. Excess solder may be removed by remelting it and flicking the excess off with a small wooden stick or toothpick.

All terminal blocks, relays, cable forms, or other equipment that is underneath terminals to be soldered, must be

covered with canvas or cheesecloth before starting to skin or solder the wires.

Review questions.—

1. What is meant by the term soldering?

2. Should solder melt at a higher or a lower temperature than the metals being soldered?

3. Why must a flux be used when soldering?

4. Which is the most common noncorrosive flux?

5. What are the two classes of solder?

6. Which class should be used to solder tin, lead, and copper?

7. What is the bit of the soldering iron made of?

8. What advantages does the electric iron have over the torch heated iron?

9. What must be done to the point of the iron before it can be used for soldering?

10. Should the blow torch be completely filled with gasoline?

11. Should high test gasoline be used in the blow torch?

12. Why is gasoline burned in the priming cup before the torch is turned on?

13. What are four requirements for good soldering?

14. Which has the best electrical conductivity, 50-50 solder or copper?

15. What are the two methods of soldering?

16. Which of the two methods should be used in soldering small terminals?

17. On which side should terminals extending downward be soldered?

18. Should the tinned point of an externally heated iron be placed in the flame of the blow torch? Why?

19. Should the melting point of the flux be below or above that of solder?

20. Which part of the Western Union splice should be soldered?

21. Is the sweating process used in soldering small terminals?

LESSON 5

LABORATORY

(Wire Students Only)

Tools and materials for operations 1, 2, 3, 4 and 5.—

*1 ea. Blow torch
1 ea. Pliers, 8-inch, side-cutting
*1 ea. Soldering iron, 1½ lb.
1 ea. File, 10-inch, with handle
1 ea. File card
*4 pcs. Wire, copper, No. 10
*2 pcs. Brass sheet (from lesson 4)
*1 pc. Wire, copper, No. 6
*1 ea. Large terminal lug
* Bar solder, rosin core solder, rags, seizing wire.

Items marked * are not placed on the memorandum receipt.

Procedure.—

Operation 1.—The blow torch will not be taken to a work bench while burning.

Check the blow torch for broken or missing parts.

Following the instructions in the lesson sheet, fill and light the torch.

Have the operation checked by the instructor.

.... Ins. check

Operation 2.—Check the soldering iron. Make sure the handle is serviceable.

Use the tinning jig furnished. Follow the instructions in the lesson sheet and tin the iron.

.... Ins. check

Operation 3.—Clean and tin one end of each of the four pieces of No. 10 copper wire. The tinned portion should be about 3 inches long. This wire is tinned in the same manner as the soldering iron, except that it is heated by the iron instead of the open flame of the blow torch. Lay two pieces of the wire together with the tinned ends overlapping. Seize the wires with a few turns of seizing wire at each end of the tinned part.

Solder this joint using the flow method.

Prepare the other two wires.

Solder this joint using the sweating method.

Note the difference between the two joints.

The best way to solder the joints in this operation is to place a piece of scrap wood on each side of the wire and place it in a vise in such a manner that the portion to be soldered is out to one side. The scrap wood will keep the heat from running into the vise and a better joint will be secured.

.... Ins. Check

Operation 4.—Solder a butt joint with the two pieces of brass sheet. Use the information contained in the lesson sheet and the illustration given in figure 5. Lay the pieces on a piece of scrap wood for the soldering operation.

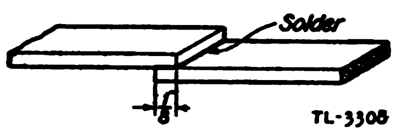

Figure 5

.... Ins. check

Operation 5.—Use the No. 6 wire and the terminal furnished. Follow the information in the lesson sheet and solder the lug to the wire according to the illustration given in figure 6.

.... Ins. check

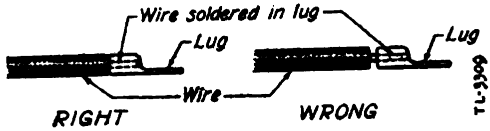

Figure 6

................................Ins. check

After completing Operation 5, the student will return to the supply room, all tools and materials left over.

Tools and materials for operations 6 to 16 inclusive.—

Report to instructor before drawing equipment for operations 6 to 16.

*1 ea. Terminal block frame
 1 ea. File, with handle
 1 ea. Soldering iron, electric (TL-117)
 1 ea. Pliers, long-nose (TL-126)
 1 ea. Pliers, diagonal (TL-103)
 1 ea. Insulation stripper.
*2 pcs. 20-pr. switchboard cable
*2 ea. Brass rods, ¼ inch x 12 inch
* Lacing twine
* Rosin core solder
* Rags

Items marked * are not placed on the memorandum receipt.

Operation 6.—Clean and tin the electric soldering iron.

................................Ins. check

Operation 7.—All operations with the terminal rack will be performed with the bottom of the rack on the work bench. In this position, the parts mounted on the rack present the same appearance as the parts of a switchboard or main frame.

Clean all of the terminals on the frame. This is best done by heating the terminals with the electric soldering iron and flicking the excess solder from them with a small wooden paddle.

................................Ins. check

Operation 8.—Lash a piece of the 20-pair switchboard cable to the frame, with the braid of the cable about ½ inch below the vertical terminal block. Separate all of the pairs in the cable and twist the ends of each pair together. Use the following table and distribute the pairs, starting at the top of the terminal block, with pair No. 1.

Colored Wires	*Mate*
Pair No. 1 Blue	White
No. 2 Orange	"
No. 3 Green	"
No. 4 Brown	"
No. 5 Slate	"
No. 6 Blue-White	"
No. 7 Blue-Orange	"
No. 8 Blue-Green	"
No. 9 Blue-Brown	"
No. 10 Blue-Slate	"
No. 11 Orange-White	"
No. 12 Orange-Green	"
No. 13 Orange-Brown	"
No. 14 Orange-Slate	"
No. 15 Green-White	"
No. 16 Green-Brown	"
No. 17 Green-Slate	"
No. 18 Brown-White	"
No. 19 Brown-Slate	"
No. 20 Slate-White	"

Note.—The color code given above is standard for all types of coded switchboard cables, whether braid or lead covered.

.... Ins. check

Operation 9.—Place the pairs under their respective rows of terminals. Hold the pairs tightly in place and at the same time push each pair sharply back against the fibre strip, in which the terminals are mounted, with the blunt wood stick. Then lay the ¼ inch brass rod between the base of the block and the back row of terminals, to hold the wires in place.

Lay the other rod in the same position on the opposite sides of the block and lash the protruding ends of the rods firmly together with lacing cord. Pull all pairs tight so that there is no slack between the cable butt and the terminal block.

..................................Ins. check

Operation 10.—Separate the first pair of wires. Lay the white wire across the edge of the mounting strip so that it will be out of the way. Bend the coded wire into the notch of the top terminal of the second row. The terminal rows are counted from the front to the back of the terminal block. The next step is to remove the insulation from the wire. This may be done with either the long-nose pliers or the insulation stripper. *Do not start to remove the insulation at the point marked on the wire by the notch of the terminal.* Drop down toward the end of the wire about $\frac{1}{8}$ of an inch and remove the insulation for a distance of about 1 inch. Hold the wire under the terminal and push the insulation back until the part of the wire that goes into the notch is uncovered. Remove all tarnish or enamel from the wire. Wind the loose ends of the insulation tightly around the wire in such a manner, that the insulation comes under the terminal but does not enter the notch. Bend the bared part of the wire into the notch and lay it across the top of the terminal at an angle of 45 degrees toward the rear of the terminal block. It is necessary to leave the insulation long and push it back on this type of wire, otherwise when the iron is used to solder the connection the loose ends will unravel and this might cause a short circuit.

Solder the connection and inspect each separate connection for the faults listed below:

a. Insulation in notch of terminal.
(Connection must be unsolderèd and insulation pushed back.)

b. Chalky solder. (Not enough heat)

c. Rosin core joints. (Not enough heat)

d. Solder not adhering to wire.
(Must be unsolderèd and wire scraped.)

e. **Wire not laying against terminal.**

(Hold wire tight, melt solder and let solder set before releasing wire.)

After the connection has been inspected, and all faults corrected, cut the excess wire off as close to the terminal as possible. If the student is in doubt as to whether the connection has been soldered properly, have the instructor check it before soldering others. Continue with the coded wires until all 20 have been soldered.

..................................Ins. check

Operation 11.—**Solder the white wires to the first row of terminals on the block.**

..................................Ins. check

Operation 12.—**Lash another piece of switchboard cable to the left and at the back side of the terminal block mounted horizontally. Place and solder the wires using the same method as that for the vertically mounted block, except that wires are wrapped from left to right so that the soldering is done on the right side of the terminal. When finished and checked for faults, submit to the instructor for approval.**

..................................Ins. check

Operation 13.—**Run three pairs of lacquered cross-connecting wires from the vertical to the horizontal terminal block. These wires are run on the opposite side of the blocks from the cable. This wire is not dressed back against the fanning strip. Each pair of cross connecting wires should have approximately 3 inches of slack. Solder the white wire to the first row of terminals and the colored wire to the second row. Check the connections for faults and submit to the instructor for approval.**

..................................Ins. check

Operation 14.—**Solder a piece of scrap wire at least 6 inches long to each drilled terminal on the lamp strip.**

..................................Ins. check

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Operation 15.—Solder a piece of scrap wire at least 6 inches long to the center terminal of each group on the jack strip. Submit to the instructor for approval.

..............................Ins. check

Operation 16.—Solder a piece of wire to each of the terminals of the 5-pair section of vertical protectors. The insulation of the wire should come up to, but not enter the notch. In no case will the distance between the notch and insulation exceed 1/16 of an inch. When attaching wire to this type of terminal proceed as follows: Remove insulation at the proper point, grasp wire at the end with a pair of long-nose pliers and make one complete wrap around the terminal, starting with the wire in the notch. Upon completion of this wrap, bend the free end of the wire down along the face of the terminal and cut it off within 1/32 of an inch of the bottom. Solder the connection on the face of the terminal.

LESSON 5A

WIRING OF RADIO EQUIPMENT, CORDS AND PLUGS

(For Radio Students Only)

1. **Bus wiring.**—Bus wire for radio equipment is usually No. 14 B&S gauge, or larger tinned copper wire. This wire may be round or square. Heavy, enameled copper wire may also be used for bus wiring. The tin or enamel coating on the bus wire prevents corrosion and in the case of the tinning, simplifies soldering.

Bus wire is used where a large current or a high frequency current is to flow through the wire. Bus wire makes a very strong job mechanically, however, if there is any danger of it coming in contact with other wires in the set, it should have some sort of insulation placed over it.

There are two methods of joining one piece of bus wire to another. The butt joint and the loop joint. See figure 7.

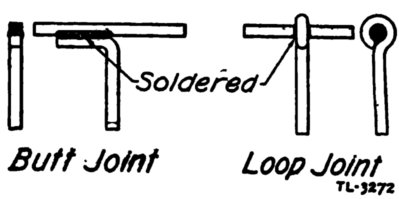

Figure 7

In the butt joint, one end of the wire to be soldered to the other is bent to a right angle to form an "L." The bent over part should be from one-fourth to three-eighths of an inch long. The bend must not be too sharp or the wire will be broken. Solder is then run in between the wires, a small amount of solder is built up on the joint. This type of joint is usually used when wiring with square bus wire.

The loop joint is used when wiring with round bus wire, or with enameled wire. This joint is made by bending a small loop on the end of the wire to be fastened to another wire, then this loop is placed over the wire and clamped in place with a pair of pliers. The joint is then soldered. The solder *must* be run in the loop.

Comparison of the two connections show the loop joint to be much stronger than the butt joint as the loop joint has added strength, because one wire is actually clamped around the other. The strength of the butt joint depends on the *solder only*.

When enameled wire is to be used, the enamel must be removed from the wire before soldering. A fine line should be scribed around the wire,. then the enamel scraped off from that point to the end of the wire. This makes a neat job. When making a joint in the middle or part other than the ends, two lines are scribed and the enamel removed between these two lines.

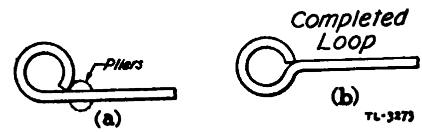

Figure 8

2. Loop bending.—It is sometimes necessary to bend loops where a wire is to be fastened around a screw. This is best accomplished with the aid of a pair of long-nose pliers. The loop is made by holding the extreme end of the wire in the points of the pliers, the left thumb resting on the wire and partly on the points of the pliers. Make a slight bend on the end of the wire, the amount of this bend will depend on the size of the loops required. Move the pliers slightly back on the wire and make another bend, continue until the loop is completely formed. Place the pliers at A, as in figure 8, shape the loop to look like the figure marked "completed loop."

A loop in stranded wire is made in the same manner; however, it is necessary to clean and twist the strands together,

then tin the wire before a satisfactory loop can be completed.

3. Cable wiring.—Cable wiring is used where a number of wires follow the same path. The wires are laced into a form, either before or after being soldered to their respective terminals, depending on the type of work being done. The wires are laced together with the lock stitch, illustrated in figure 9. *Do not use a half-hitch.* This knot will not hold the form together if the lacing cord is broken.

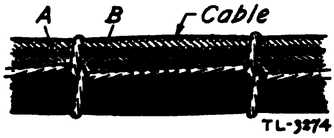

Figure 9

Note the points on the diagram in figure 9 marked "A" and "B." At these points the twine must be on the *under* side. If either "A" or "B" is on top when the stitch is made, it is called a *half-hitch* stitch. When the half-hitch is used it will come loose if the twine is broken.

A figure eight knot is used to start the lacing. The short end of the cord should be carried under the first two stitches and then cut off. When the cable lacing is completed, the twine is anchored by placing two or three stitches behind the last stitch of the form. See figure 10.

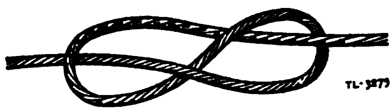

Figure 10

Do not lace wires carrying *high voltage* or *high frequency* currents in a cable form with other wires.

A type of wire, called "pushback" is normally used to wire radio sets. It is simply a tinned copper wire with an insulation that can be easily pushed back from the end. This saves time and gives the installation a neat appearance.

Shielded wire is usually grounded to the frame of a set or if used externally in vehicles, to the body of the vehicle.

This is accomplished by either soldering a pigtail and lug to the shield or unraveling the strands of the shielding, twisting them to form a wire, and soldering this to the nearest ground. If the ground is not near enough to the point of termination to use this method, solder a piece of stranded pushback wire to the shield and run it to the ground.

4. Cords and cordage.—

Definition.—Cordage is the bulk cable used in the fabrication of cords. *Cords* are pieces of cordage cut to the proper length and with the ends prepared for the application of plugs. They may be prepared with or without the proper plugs.

Use.—There are many types of cords used in the installation of radio sets. Cords are used to interconnect the component parts of radio sets in aircraft, portable and vehicular installations. The type of cord to be used is determined by the particular installation and is covered by instructions for the installation of each different type of equipment.

Description.—Cordage in general has from 2 to 8 conductors, each conductor having an insulating cover of rubber. The conductors are twisted together, jute or cotton packing being added to give shape to the cord, and covered with an insulating tape which, in turn, usually is covered by the shield. The shield is composed of small tinned copper wires braided around the taped conductors. The shield is covered with a rubber jacket which insulates and protects the entire assembly. In some cases the shield is on the outside of the rubber jacket. This last type of cordage is used extensively in aircraft and vehicular installations where bonding of the cords at frequent intervals is essential. The conductors in cordage are generally color coded, each conductor having a different color rubber insulation to facilitate the tracing and connecting of the conductors. When the conductors are not coded, an ohmmeter or some similar means must be used in tracing the conductors. Cords, in most cases, are fitted with plugs which fit into sockets on the equipment thus making the necessary connections between the units. This is not true in all cases

however. In some equipment the cords are connected to terminal strips in the units.

Common troubles.—One of the most common troubles to be found in cords is the breakage of conductors at or near the plugs or at points where the cord is bent too sharply, as in going around the corner of some piece of equipment. A cord should be long enough so that no strain is placed on it at any time. Another common trouble is twisting of the cord in the plug, thus shorting or breaking the conductors in the plug. Be sure the plug is properly clamped on the cord.

5. Plugs and sockets.—

Use and description.—Plugs are used on the ends of most cords to facilitate the connecting of the cords to the units. The plugs fit into sockets which are usually mounted in the various units of the equipment. There are so many different types of plugs and sockets that no attempt will be made to describe them in this lesson, as the student will become more familiar with the various types as he works with the equipment. Most plugs and sockets have the connecting pins so positioned that the plug can only be inserted into the socket in the correct position. Most plugs are also equipped with some locking device to prevent the plug from being pulled out of the socket accidentally. Plugs and sockets usually have the pins and connections numbered or marked in some manner so that they may be properly connected. The wiring diagrams of the equipment shows these numbers or markings so that trouble shooting and repair of the equipment is simplified.

Common troubles.—One of the most common troubles found in plugs and sockets is poor connections between the plug and socket. One type of socket commonly used has banana plugs for the socket pins. The springs on these pins become compressed and fail to make a good connection. This may be cured by spreading the springs with a small screwdriver or a scriber. Plug shells frequently become so battered from dropping and other abuse that they do not fit the sockets properly. If not too badly damaged they may be reshaped and continued in service. The locking devices

sometimes become damaged through accident or abuse. If not too badly damaged they should be repaired and continued in service.

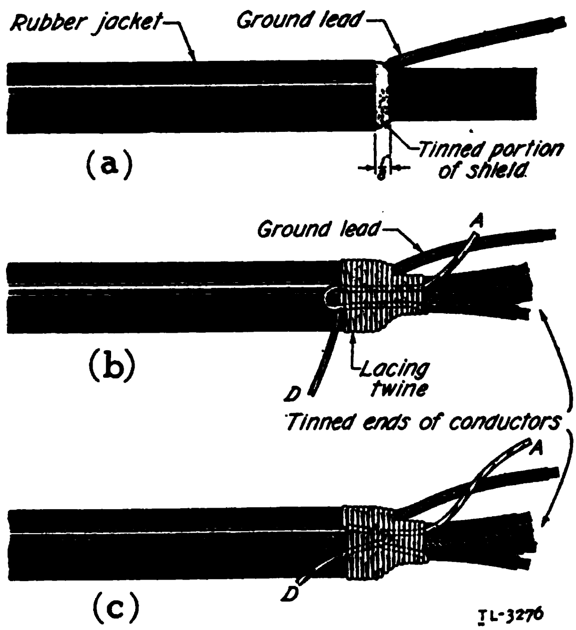

Figure 11

6. Repair of cords.—The following information on the repair of cords is necessarily of a general nature. The instruction books covering the different types of equipment and the installation of the units usually covers the makeup of the associated cord. In all cases these instruction books should be consulted and local instructions followed when repairing or making cords.

Preparation of cords.—Rubber jacketed cords will be considered in this lesson since this is the most commonly used type. The first step is to cut the cordage to the proper length. If an old cord is being used or repaired the conductors should be checked for continuity with an ohmmeter or by some similar means. Next cut off the rubber jacket for about 1 inch being very careful not to cut into the shield. Diagonal pliers are the proper tool to use in cutting off

the jacket. Tin the shield for a space about ⅛-inch wide next to the rubber jacket. Refer to figure 11a.

The next operation is to solder the ground lead to the shield, where the shield was tinned. Remove about 1½-inch of insulation from one end of a 6-inch piece of No. 18 stranded, rubber covered wire. Wrap the bare end around the tinned portion of the shield and solder into place. Be sure it is well soldered. Next cut the shield off back to the tinned portion at the same time removing the insulating tape and cutting out the cotton or jute packing cords. Be careful not to cut the insulation on any of the conductors. Now the insulation may be removed from the ends of the conductors and the ends tinned. Do not remove too much insulation, an eighth of an inch being sufficient in most cases. The insulation on the conductors is usually live rubber and unless extreme care is used too much insulation may be pulled off. Do not use a knife to remove the insulation. Nip it loose with the points of the diagonal pliers. Twist the strands of each conductor together neatly and tin them as soon as the insulation is removed. As soon as this operation is finished the end of the cord will be served with waxed lacing twine. The Signal Corps type number of the twine generally used for this purpose is RP-13. The following explanation and figures 11b and 11c will show how this serving is applied.

A piece of twine about 18 inches long is used. One end of the twine is laid along the cord in a loop as shown by ABC in figure 11c. Leave end of twine A about 4 or 5 inches long and end of loop B about 1 inch back from the end of the jacket. Beginning at C wrap 3 or 4 turns of twine around the conductors drawing the twine very tight. Do not include the ground lead when making these first 3 or 4 turns. Now include the ground lead and continue wrapping the twine until about 4 turns are made over the rubber jacket. Keep the twine pulled tight at all times and keep the turns as close together as possible. Make the serving look as neat as you can by working the turns, into place with the fingers, as they are put on. Now put the end of the twine D, figure 11b, through the loop B. Pull on end A pulling loop B under the wrapping as shown in figure 11c.

This draws the end D under the wrapping at the same time and thus ties the serving in place without the use of knots. Cut off the ends A and D close to the wrap and the job is finished.

Preparation of plugs.—The plugs should be inspected to see that they are of the proper type and are clean and free from corrosion. If old plugs are to be used, the old solder should be removed and the plugs thoroughly cleaned. When removing solder from the plugs having the pins or jacks permanently fastened into a bakelite block, care should be exercised not to use too much heat as this causes the bakelite to swell and the shell will no longer fit over it. Too much heat also causes the bakelite to break down and results in electrical leakage between the pins. See that all screws are in place and have lock washers on them, and that the locking device is not damaged.

Soldering.—When soldering the conductors into the plug do not hold the soldering iron on the connection too long. As stated previously, this will cause trouble during and after assembly. Be sure that the necessary plug parts are threaded on the cord, before soldering the plug in place. Check your wiring diagram and color code thoroughly before starting to solder the conductors. Double check all connections while soldering. If there is any doubt as to the colors of any of the conductors, use an ohmmeter or some similar means to check them through. Do not use too much flux or solder. Surplus flux and solder should be cleaned from the connections and plugs. Be sure that all strands of the conductors are soldered into place. Free strands may cause short circuits or grounds. See that the insulation is not damaged on the conductors. If necessary, insulating tape or cloth should be used to insulate the conductors.

Assembly of cords and plugs.—When all connections have been soldered and inspected, the plugs may be reassembled. When fitting the plug parts together be sure that the conductors are not pulled tight or twisted together any more than is absolutely necessary. See that all the screws used in the assembly have lock washers on them. Be sure that the locking device is free and operates properly. See that the cord is

properly clamped in the plug. If necessary a layer of rubber tape should be used under the cord clamp.

Testing of cords.—After assembly it is advisable to check the cord with an ohmmeter or by some similar means to see that the conductors connect through the proper pins at each plug. The most satisfactory method of testing the cord is by installing it in the proper equipment, and trying it under actual service conditions. Quite often a cord will develop trouble in service that does not show when tested by other means.

LESSON 5A

LABORATORY

(For Radio Students Only)

Tools and materials for operations 1 to 6 inclusive.—

*1 ea. Blow torch	*4 pcs. Wire, copper No. 10
*1 ea. Soldering iron	*4 pcs. Wire W-50
1 ea. Pliers, 8-inch side-cutting	*1 pc. Wire, copper No. 6
1 ea. Pliers, long-nose (TL-126)	*1 ea. Large terminal lug
1 ea. File, with handle	*2 pcs. Brass sheet (from lesson No. 4)
1 ea. File card	*Bar solder, rosin core solder, rags, seizing wire

Items marked * are not placed on the memorandum receipt.

Procedure.—

Operation 1.—Check the blow torch for broken or missing parts. Fill and light the blow torch, using the information contained in lesson 5. Have the operation checked by the instructor. *The blow torch will not be taken to the work bench while burning.*

Operation 2.—Check the soldering iron. Make sure the handle is serviceable. Use the tinning jig furnished. Follow the information contained in lesson 5 and tin the iron.

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Operation 3.—Clean and tin one end of each of the four pieces of No. 10 copper wire. The tinned portion should be about 3 inches long. This wire is tinned in the same manner as the soldering iron, except that it is heated by the soldering iron instead of the open flame of the blow torch. Lay two pieces of the wire together with the tinned ends overlap-

ping. Seize the wires with a few turns of seizing wire at each end of the tinned part. Solder this joint, using the flow method. Prepare a joint with the other two wires. Solder this joint, using the sweat method. Note the difference between the two joints. The best way to solder the joints in this operation is to place a piece of scrap wood on each side of the wire, and place it in a vise in such a manner that the portion to be soldered is out to one side. The scrap wood will keep the heat from running into the vise and a better joint will be secured.

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Operation 4.—Solder a butt joint with the two pieces of brass sheet. Follow the information contained in lesson 5, and the illustration given in figure 12. Lay the pieces on a piece of scrap wood for the soldering operation.

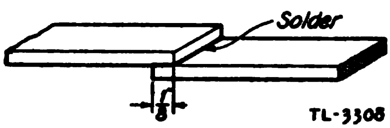

Figure 12

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Operation 5.—Use the No. 6 wire and the terminal lug furnished. Follow the information contained in lesson 5 and the illustration given in figure 13. Solder the wire and lug.

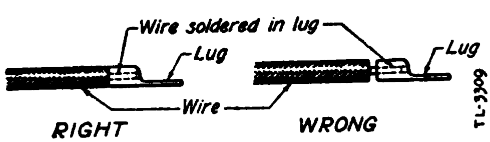

Figure 13

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Operation 6.—Use the wire W-50. Make two Western Union splices. Solder one splice using the flow method, the other using the sweat method.

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After completing operation 6, the student will return all tools and material left over to the supply room. See instructor on floor of soldering classroom, before drawing equipment for operations 7 to 14.

Tools and materials for operations 7 to 14 inclusive.—

1 ea. Soldering iron TL-117
1 ea. Pliers, 6-inch side-cutting (TL-13)
1 ea. Pliers, long-nose (TL-126)
1 ea. Pliers, diagonal (TL-103)
1 ea. Knife TL-29
1 ea. Small screwdriver
1 ea. Chassis
1 ea. Plug PL-50
1 ea. Plug PL-61
*1 pc. Wire W-50
*6 pcs. Wire No. 14, enameled
*1 bundle Wire, for chassis wiring
*3 Terminals, mounted on block
*1 pc. Cordage CO-130
*1 pc. Cordage CO-138
*Small terminals assorted, bus wire tinned, rosin core solder, rubber and friction tape, lacing cord, stranded pushback wire.

Items marked * are not placed on the memorandum receipt.

Inspect models on display board and table, before doing any of the operations below.

Operation 7.—Clean and tin the electric soldering iron.

Operation 8.—Solder a terminal, TM-10 on one end of the lamp cord.

Solder a lug on each end of the No. 14 enameled wire. Use information contained in lesson 5 and solder the lug according to the illustration given under operation 5.

Solder a short piece of solid conductor pushback wire to each terminal on the block furnished.

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Operation 9.—Use the information contained in lesson 5A, solder a butt joint. This joint is made with the square bus wire. Two satisfactory joints must be completed.

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Complete two soldered loop joints.

Operation 10.—Use the No. 14 enameled wire to practice bending loops. One satisfactory loop must be completed to fit the machine-screw furnished.

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Operation 11.—This operation consists of wiring a chassis according to figure 14 and information. The finished job must present a neat appearance. All soldering flux must be removed. The bus wiring shall be straight and all corners shall be square. Soldered connection must be smooth.

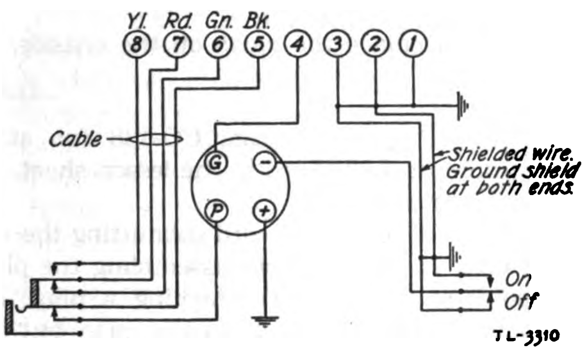

Figure 14

Use pushback wire, connect terminals 5, 6, 7 and 8 to the four lower terminals on the jack. These wires must follow the same path so that they can be laced into a cable.

Using lacing twine, lace the four wires together.

Using enamel wire, connect the top terminal on the jack to the "P" terminal on the tube socket.

Using enamel wire, connect the "G" terminal on the tube socket to terminal No. 4 on the terminal strip.

Using enamel wire, connect the negative (—) terminal of the tube socket to the center terminal of the switch.

Using the shielded wire, connect the terminals 2 and 3 of the terminal strip to the two remaining terminals on the switch. The shield of these two wires must be grounded. That is, the shields are connected together by direct soldering or by soldering a piece of wire to both shields and then soldering a lug on the end of the wire. The lug is then bolted

to the chassis with a machine-screw.

Using square bus wire, connect terminal No. 1 of the terminal strip to the nearest ground lug.

Using square bus wire, connect the positive (+) terminal of the tube socket to the ground lug.

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Operation 12.—Remove all wiring from the chassis. Clean the terminals of all solder by heating the terminal and then brushing the solder off with a clean cloth. *Do not file or scrape the terminals.*

Operation 13.—Replace the parts on the chassis.

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Operation 14.—Prepare cordage CO-138 for attaching plug. Use the procedure outlined in the lesson sheet. Submit the work to the instructor.

Attach the plug PL-61 to the cord submitting the work to the instructor for checking before assembling the plug.

Prepare cordage CO-130 for attaching a plug. Do not solder a ground lead to the shield in this case, but unbraid the shield and twist it into two pigtails. Tin these pigtails thoroughly. Cut the conductors and pigtails to about 3/8-inch in length. Remove 1/8-inch of insulation from the conductors and tin them. Solder a terminal TM-142 to each conductor and each pigtail. Submit the work to the instructor.

Attach the plug PL-50 to the cord after taping the shanks of the terminals to prevent their shorting. Be careful when putting the nuts and screws in place that they are not scarred unnecessarily. Submit the work to the instructor for checking.

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LESSON 6

WOODWORKING

1. **General.**—Woodworking is the art of taking rough lumber as it comes from the mill and turning it into a finished product. Woodworking is divided into a large number of special operations, only those pertaining to the use of simple hand tools will be covered here. Woodwork, in order to present a pleasing appearance when finished, should be cut, shaped, jointed and assembled with care. Even though the completed piece is not to be painted or stained, it will hold together better and last longer if the parts are cut square and the joints fit tightly.

2. **Holding devices.**—The most common holding devices are the work bench and the vise. A heavy, well braced work bench is necessary regardless of the type of woodwork being done. It is a convenient place to layout and assemble the work, keep the tools required for the job, and store the fastening devices and finishing material required. The bench should be equipped with a vise, bench stop, drawer and shelf.

The bench stop is simply a steel plate, with teeth on two sides, which may be raised or lowered by means of a screw in its center. The bench stop acts as a backing for surface planing or where pieces are too small or thin to be held in the vise.

The vise usually consists of two jaws faced with wood and a steel screw equipped with a handle. It is used to hold the wood stock during the cutting and smoothing operations. The wood faces on the steel jaws prevent the wood stock from becoming marred. It is a very poor practice to hold a piece of wood in a metal working vise. If this becomes necessary, place a piece of scrap stock on each side of the piece being cut or shaped.

3. Laying out the work. —The more care exercised in measuring the pieces, the less time and labor the worker will be required to expend in squaring and finishing the parts. The layout devices most frequently used in hand woodwork are: the try square, steel square, marking gauge, 2-foot boxwood rule and the 6-foot zigzag rule.

The try square consists of a steel blade, 4 to 12 inches long set in a beam or head of wood or steel. The angle between the inner edge of the blade and the beam is 90 degrees. The outer edge of the blade is graduated in fractions of an inch, the smallest division usually being ⅛th of an inch. In addition to being used as a layout tool, the try square is used to test the straightness and flatness of small pieces of wood, and test edges and ends for squareness.

The steel square is similar in construction to the try square, except that it is usually made in one piece and is not so accurate. The shorter part is called the tongue, the longer part is known as the blade. There are several graduations found on the edges of the steel square. Usually they are ⅛, 1/4, 1/10, 1/12 and 1/32 parts of an inch. The square also normally contains a board foot scale and a rafter table.

Marking gauge.—This tool consists of a square ruler, with a pin set in one end, a head with a square hole in its center and a set screw. The ruler slides in the hole in the head permitting measurements from 1/16 of an inch to 6 inches to be laid off along the grain.

Rules.—The 2-foot boxwood rule and the 6-foot rule are used in general measurements, to estimate the number of pieces that may be cut from a large board and when constructing large frames or braces. These rules should not be used where a high degree of accuracy is required.

Transferring the dimensions.—A pencil with a thin flat point should be used to mark with the grain if the marking gauge cannot be used. A sharp knife is best suited for marking across the grain. Knife or pencil should have the upper end tilted away from the square or rule. This causes the marking end to run close to the layout device, giving an accurate measurement.

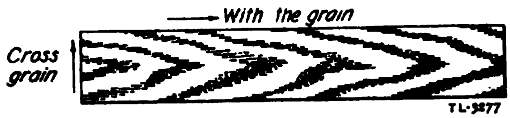
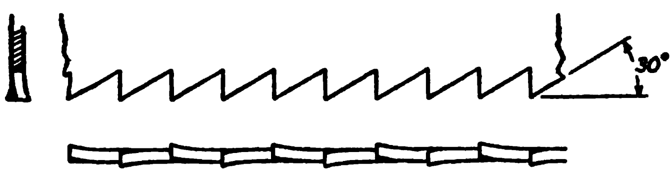


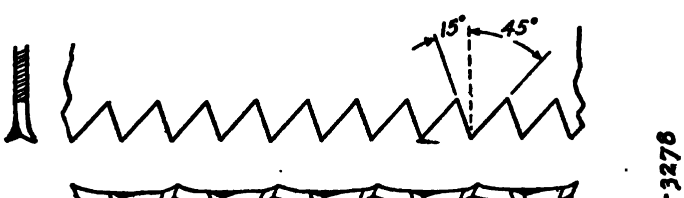
Figure 1

4. Cutting out the parts.—All parts required should be cut first. Do not cut them exactly to size, except where very rough work is being done, as some waste wood is required for smoothing and squaring. Letter or number each piece as it is cut to eliminate duplication of parts. The saw cut should be made outside of the line never exactly on it. Splitting the line will cause the piece to be too small.

Pieces are usually cut out of the lumber stock with some type of rip or crosscut saw. The rip saw is used to cut with the grain, the crosscut saw cuts across the grain. A cut with the grain separates the long wood fibers, a cut across the grain severs them. See figure 1.



Teeth of Rip Saw



Teeth of Crosscut Saw

Figure 2

Saws, with a few exceptions, have their teeth alternately bent out of line. This is called set. It makes the saw cut or or kerf wider than the saw back and prevents binding. Saws used on damp spongy lumber require a greater set than

those used on dry well seasoned lumber. The principal differences between the rip and the crosscut saws are: The shape of the teeth, the way the teeth are sharpened, and the amount of set. See figure 2.

To make a cut with either type of saw, the following rules should be observed.

Start the cut with the end of the saw, using a back stroke.

After the kerf is started, use a long stroke, running the saw in line with the arm and shoulder after the cut is started. The correct angle between the saw and the work for ripping is 60 degrees, for cutting across the grain 45 degrees. If possible the work should be held in a vise or supported on a sawhorse or other frame, high enough from the floor to prevent the end of the saw from striking. This gives the operator the best control over the saw. A very square and even cut can be made across the grain by placing the beam of a square on the work, with the blade in line with the proposed cut. The saw blade is then placed along the blade of the square, which acts as a guide. The beam of the square is moved toward the operator as the cut is increased. See figure 3.

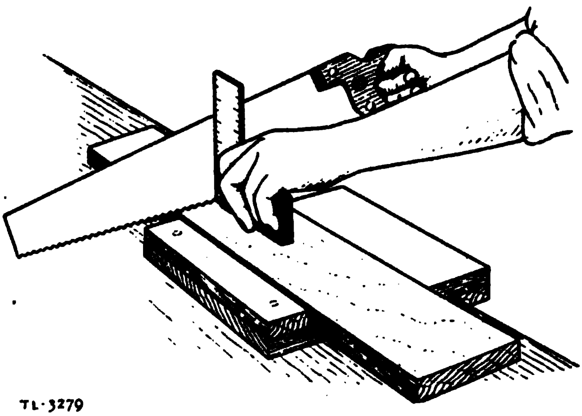


Figure 3

Selecting the saw.—Saws have a number stamped on the blade near the handle which indicates the number of points per inch. The larger this number, the finer the saw. Rip saws

usually run from 5 to 9 points, crosscut saws from 5 to 11 points. The back saw, a crosscut saw used for finer cuts, has from 12 to 16 points per inch.

The 5½-point rip saw, 26 inches long is best for general work. A finer saw should be used for thin material. The 10-point crosscut saw, 26 inches long, is the most popular and and is very efficient for general work. Lumber 2 x 4 inches and heavier should be cut across the grain with a 7 or 8 point saw. Crosscutting thin wood, cutting mitres and other types of wood joints should be done with the back saw. This leaves an end surface which requires very little dressing.

Inside, circular and irregular cuts.—These cuts are made with the compass, keyhole and coping saws. The compass and keyhole saws have narrow, tapered blades and are used to cut out circles, braces, round corners, for circular and irregular openings, etc. The coping saw is used mainly for scroll and fret work.

5. **Planing.**—This operation brings the piece to exact size, squares it, smoothes the edges and surfaces. The plane is nothing more than a beveled cutter set in a block of wood or steel, so that the operator can use both hands and rapidly smooth, true and bring the stock to size. The plane is equipped with an adjusting lever which is used to square the cutter with the sole or bottom of the plane, and an adjusting nut which regulates the depth of the cut. A common mistake is to set the blade too far out. Take off thin shavings, not thicker on one edge than the other, and the best results will be obtained without gouging the work or clogging the plane with shavings.

Outside of having the plane cutter sharp (See lesson 1) and holding the tool as square as possible, there is very little to think about while planing. The start of a stroke is made with more pressure on the knob with the left hand than is exerted by the right. The pressure should be even in the middle of the stroke. At the end of the stroke apply pressure to the handle with the right hand and practically none with the left hand. The steps to follow when truing up stock are: Plane work face flat and smooth; plane work edge straight, square and smooth; measure and plane to width;

plane piece to thickness required; mark for square end on all four surfaces, saw and plane end, allowing a little waste stock for planing; (plane from edges to center); measure to length, cut and square second end.

Planes.—The two general types of planes are the bench and block. The block plane is used across the grain. The bevel of the cutter is turned up and the cutter is set in the plane at a low angle for ease of operation. Block planes run from about 4 to 6½ inches long. The bench plane is used with the grain. The bevel of the cutter is down and the edge is backed by a cap iron, which acts as a deflector for the shavings. The four most commonly used bench planes are:

Smooth.—5½ to 10 inches long. This plane is very useful in getting down into the hollows of a piece of wood.

Jack.—14 inches long. This is the best plane for general work.

Fore.—18 inches long. This plane is used for planing long pieces.

Jointer.—20-24 inches long. This plane is used to smooth exceptionally long pieces and even up pieces for glue joints.

6. Wood chisels.—The wood chisel is a hand guided, sharp edged cutting tool. One end is ground to a bevel from 20 to 30 degrees, the other end is equipped with a handle. This tool is made in a large variety of shapes for cutting joints, grooves, slots, fluting, wood turning, wood carving, box core work, etc. The four types of wood chisels most commonly used are:

Butt.—A short thin chisel, used like a pocket knife in confined places, such as seating a hinge or door lock.

Paring.—A long thin blade, used like a plane to remove a thin shaving from a piece that does not fit well.

Firmer.—A medium thick chisel for general work.

Framing.—A thick heavy chisel, for use on heavy timbers or other places where a severe strain is placed on the tool. The butt and paring chisels are worked by hand only, the firmer and framing chisels may be driven by a wooden mallet.

7. Mallets.—The wood mallet is a very heavy wooden hammer provided with a large cylindrical shaped head. It is used for driving wood chisels, wooden pins, etc. Mallets are sometimes made of leather, lead or brass.

8. Rasps.—The wood rasp is a tool similar to a file, except that each tooth is punched from the body of the tool. It is used for rough cutting and shaping of wood and soft metals. The rasp is used with pressure on the forward stroke only. This tool cuts very rapidly but leaves the surface very rough.

9. Wood bits.—The wood bit is a tool used for boring holes of various sizes in all types of wood. Usually it has a feed screw to draw the bit into the wood, a spur to score the outer edge of the hole to prevent splintering, and cutting lips that cut the chip out after it has been scored. The bit usually has a square taper on the end of the shank. There are three common types of wood bits.

Single twist.—This bit has a single spiral and one spur only. It is used in rough construction work. The ships auger is also a single twist bit which is used to bore holes in heavy timber. It has no spur but the cutting lip is continued vertically, which causes a heavy chip to be cut out.

Double twist.—This bit has a double spiral and two spurs and cutting lips. It cuts a smoother hole than the single twist bit. It is used for general work, also in plain cabinet and sash work.

Straight core.—This bit has a spiral milled around a straight center core, two spurs and two cutting lips. It bores a much smoother hole than the single or double twist bits, and is used in all types of cabinet and furniture construction.

In boring holes, do not run the bit completely through the wood from one side. When the point of the feed screw comes through, reverse the piece and finish the hole from the other side. This prevents splintering the surface of the wood around the hole. Wood bits are usually graduated in sixteenths. The smallest is a No. 3 or 3/16 inch, the largest, No. 16 or 1 inch. The number stamped on the shank of the bit indicates the diameter in sixteenths of the bit. Example: A number 7 bit will bore a hole 7/16 inches in diameter.

See display board for examples of wood bits.

10. **Ratchet brace. Angle brace.**—The brace is a tool used to hold, rotate and apply pressure to wood bits. It is a metal crank with a handle on one end and a chuck on the other. The chuck has two jaws to hold the square taper end of the wood bit. This chuck should never be tightened with a wrench, but by hand only. There is a ratchet located just above the chuck which permits the bit to be rotated continuously when a full sweep of the handle cannot be obtained. This feature is very helpful when boring holes in corners and attics.

The angle brace is equipped with a double sweep, connected together by means of a universal joint. This makes it more efficient in close quarters than the ratchet brace because the user can always make a full sweep with the inner handle.

11. **Draw knife.**—The draw knife is a large, sharp edged blade having at each end a handle at right angles to the blade. The blade is beveled on one side only. The draw knife is used to trim telephone poles, the quick shaping of rough parts and other dressing to shape where appearance is not critical. The draw knife is pulled toward the user when making the cut.

12. **Claw hammer.**—The claw hammer is composed of a metal head fastened onto a wooden handle. One end of the head has a flat or slightly rounded face for driving nails, the other is shaped into a claw for removing nails.

13. **The level.**—The level is used for guiding and testing. It is a bar of wood or steel, equipped with two glass tubes, both filled with alcohol and a bubble of hydrogen. One tube is located in the side of the frame, the other in the end. The level can be used to test either horizontal or vertical surfaces for levelness.

14. **The screwdriver.**—The use of this tool was described in lesson 1.

15. **Wood joints.**—There are a large variety of joints used to fasten wood parts together, from the butt joint, which is

simply placing the two pieces together at an angle and nailing or screwing them in place, to the blind dovetail which is used in the finest furniture construction. A few of the more common joints are illustrated in figure 4. Regardless of the type of joint used, the measurements must be accurate and the members cut square to insure a snug fit. A loose joint will weaken the entire structure.

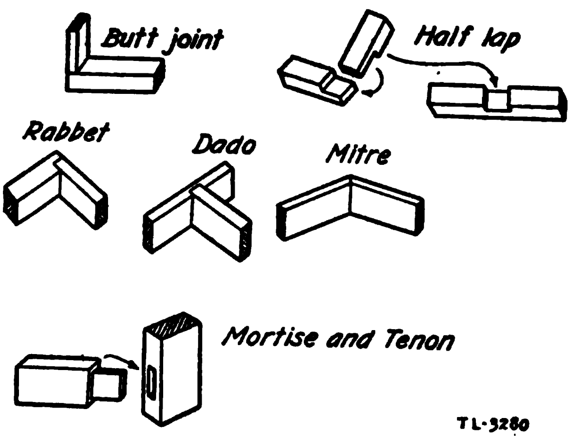


Figure 4

16. Fastening devices.—The most common devices used to hold woodwork together are: nails, screws, bolts, glue, dowels, straps, corrugated nails, spikes, etc. A few general rules to be followed when fastening wooden parts together are given below.

Metal such as hinges and locks, requires a wood screw.

Do not use a screw or nail large enough to cause the work to split.

If the nails go through the wood, they should be bent over and clinched.

Never use wood screws that go completely through the wood, as this reduces the holding power of the screw.

Where bolts are used through the wood, a washer should be used both under the head and the nut.

Nails.—The wire nail is the one most commonly used. Nails run in size from 2d (one inch) to 60d (6 inches). For

certain classes of work nails are made of copper or brass. Wire nails also may have a blue cement or galvanized finish to prevent rust. For general work, the common nail is used. This is the one with the wide head. Cabinet work requires the use of a finishing nail. This nail has a very small head. Rules have been formulated regarding the length of nails to be used for any given work, they are listed below.

General work in medium hard timber requires a nail, the penny length of which shall not exceed the thickness of the board in eighths of an inch. For example, ¾ inch lumber requires a six penny nail.

In soft wood, the nail may be one penny larger.

In hard wood, the nail should be one penny smaller.

The term penny, written as 2d, 4d, originally indicated that one thousand of these nails weighed the number of pounds indicated by the figure.

Wood screws.—Wood screws are usually made of brass, iron or steel. They are used to hold woodwork together where a neat appearance is required or greater holding power than that afforded by nails is needed. A wood screw does not injure the material as much as a nail, also they are easier to remove. If a screw is hard to drive, a small pilot hole may be bored or else the threads of the screw may be covered with soap before driving. Two other types of wood screws are: lag and drive screws. These screws have square or hex heads and are driven with a hammer or turned with a wrench. Wood screws sometimes rust or become stuck in the wood. The following methods may be used to ease their extraction. They may be tapped on the head with a hammer or the head heated with a hot soldering iron. If in a piece where appearance is not important, oil may be applied around the head and allowed to soak in. The student is referred to lesson 3 for the method used in measuring wood screws.

17. Wood finishing.—The plane usually leaves some small ridges or rough places on the surfaces of piece of wood. Before the work can be painted or stained, these must be removed. There are a great many elaborate methods used to

prepare wood for finishing, only the simplest is described here.

Wood scraper.—This tool is a thin piece of sheet steel, with the sides filed flat and a portion of the filed surface turned over to form a burr. It is used where the grain is not even and the plane has gouged out portions of the wood. The scraper must always be used with the grain, running it across the grain makes the surface rougher instead of smoothing it. The scraper should be pushed away from the operator as this gives the best control over the tool.

Sandpaper and garnet paper.—The scraper will not leave a surface very smooth as it cuts at a fairly rapid rate, and leaves some of the wood fibers turned up in the form of fuzz on the surface. An abrasive paper is used to cut this fuzz from the wood. "Sandpaper" consists of small particles of flint glued to a paper backing. Garnet paper is made in the same way except that the abrasive material cuts much better than flint and lasts longer.

Sandpaper is graded from 3/0 to number three, those grades in the zero series are considered fine, while those in the whole number series are considered coarse. Garnet paper is graded in the same way, except that the finest grade is 7/0.

A fairly coarse grade is used first and then the piece is finished with a fine grade. Always sand with the grain, sanding across the grain, scores the wood and this will show thru a stained finish.

Sandpaper is also used to finish or polish some of the softer metals.

Review questions.—

1. Name the two common holding devices required for woodwork.

2. Name the two parts of the try square.

3. Name the two parts of the steel square.

4. What two tools are used to lay off dimensions across the grain?

5. Name two tools used to cut out wooden parts.

6. Name the two general classes of planes.

7. What is the rasp used for?

8. A wood bit has the No. 6 on the shank. How large a hole will it bore?

9. Name two types of braces used to hold wood bits.

10. Name two types of common wood joints.

11. Name three fastening devices.

12. Which has the greater holding power, nails or screws.

LESSON 6

LABORATORY

Tools and materials.—

Tools and materials that are required to perform the job assigned to you by the instructor.

Procedure.—

Report to the instructor for an assignment to a job. When all work is completed, submit to the instructor for approval.

The student should be able to identify any tool described in the lesson sheet. Those with which he is not familiar may be drawn from the supply room and taken to the instructor for explanation.

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LESSON 7

MISCELLANEOUS TOOLS

1. **Splicing clamps, 10 inch (LC-24).**—The splicing clamp is a tool used to make Western Union and sleeve splices in the larger sizes of wires. In lesson 2, the student learned to splice wires with the fingers, aided by small pliers. This method is not satisfactory for copper and phosphor bronze wires from 12 to 6 gauge and galvanized iron wires from 12 to 9 gauge.

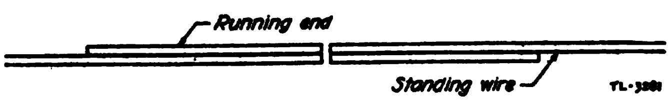

Figure 1

The Western Union splice is not satisfactory for joining wires of the sizes indicated in the paragraph above. It does not give as good an electrical contact as a sleeve splice and should be used only in an emergency, where there are no sleeves available. In addition, hard drawn copper wire nicks easily because it is very brittle. A nick in the Western Union splice, made while forming the neck or buttons will cause the wire to break very quickly. The steps required to form the Western Union splice with the aid of splicing clamps are illustrated in figures 1, 2, and 3.

Clean copper wire with No. 0 emery cloth and wipe galvanized iron wire with a cloth before splicing.

Overlap the ends of the wires about 12 inches.
Turn the clamps so that the single holes are on the inside of the handles, select the hole that fits the wire being spliced, place the clamps on the wires as indicated in figure 2 and fasten the handles.

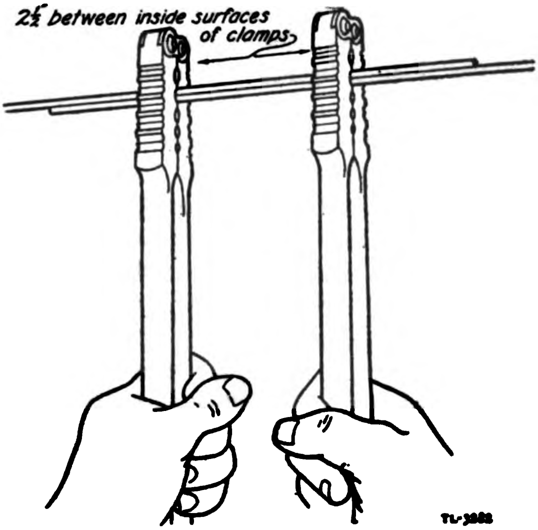

Figure 2

Rotate the right hand clamps one and one-half turns in one direction and the left hand clamp one and one-half turns in the other direction. This should form the neck, which is required to have six half turns or three full turns. As soon as the turns in the neck have been checked, remove both clamps. Place one clamp over the last turn of the neck but *do not fasten the handles*. This will damage the wire and weaken the splice.

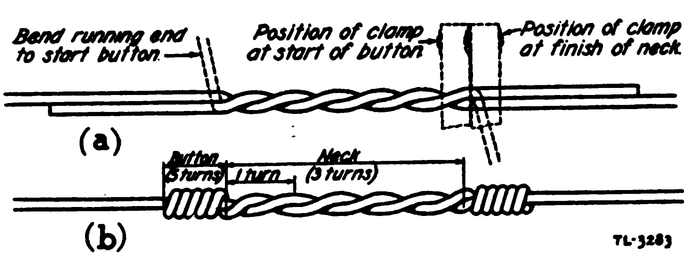

Figure 3

Use the 8-inch pliers and place the five close turns, which form the button, around the standing wire and cut off the excess portion of the running wire as short as possible. Move

the splicing clamp to the other end of the splice and form the other button. The turns in the buttons should be as close together as possible and tightly wrapped about the standing wire.

Splicing sleeves are made of copper, for copper and phosphor bronze wire, and tinned steel for joining galvanized iron wire. Clean all dirt from the tubes of the sleeve before inserting the wire. The steps required to make a sleeve splice are illustrated in figure 4. Turn the splicing clamps so that the double holes are on the inside of the handles.

Rotate the clamps as described for Western Union splices. When six half turns have been placed in the sleeve, bend the ends of the wire back over the sleeve and cut off as illustrated in figure 4.

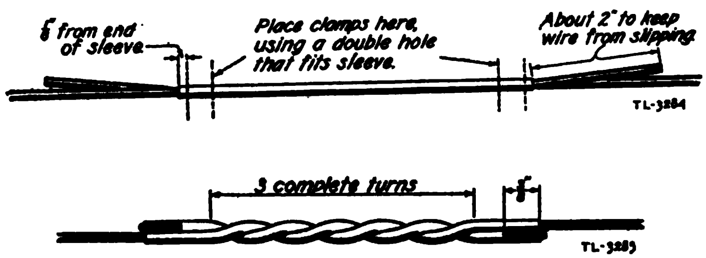

Figure 4

2. **Electrician's scissors.**—These scissors are a short heavy bladed tool used to cut soft copper wires not larger than 18 gauge and to remove paper insulation from small wires. The back of the blades are corrugated to aid in the removing of insulation and cleaning the wire. The electrician's scissors find their greatest use in splicing cables. These cables have a great many pairs of paper covered wires in them, and if pliers were used to remove insulation it would require a great deal of extra labor in picking them up each time the insulation was removed from a wire, laying them down again to twist the joint and so on. The scissors can be held in the hand, with one finger through one of the loops in the handles and are always ready for use. The method of holding and cutting with the scissors is illustrated in figure 5.

3. Wrenches.—The wrench is a tool used for gripping and turning bolt-heads, nuts and pipes. Wrenches are divided into three general classes: plain or fixed, adjustable and socket.

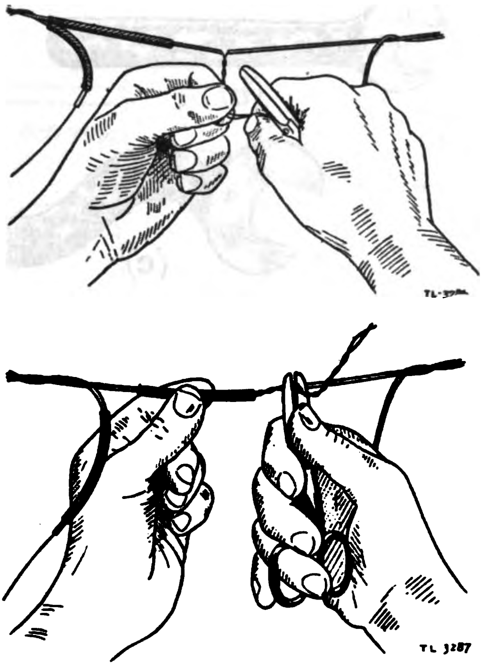

Figure 5

Plain or fixed wrenches.—This type of wrench is made to fit only one or two sizes of bolts or nuts, depending on whether it is single or double ended. Some examples of fixed wrenches are illustrated in figure 6.

Adjustable wrenches.—Since the average mechanic cannot have a complete assortment of fixed wrenches, a type of wrench with one fixed and one movable jaw is made. There are three general types of adjustable wrenches: monkey, crescent and Stillson. The monkey and crescent wrenches are used for nuts and bolt-heads. The Stillson wrench is used for pipes only because the toothed jaws will damage

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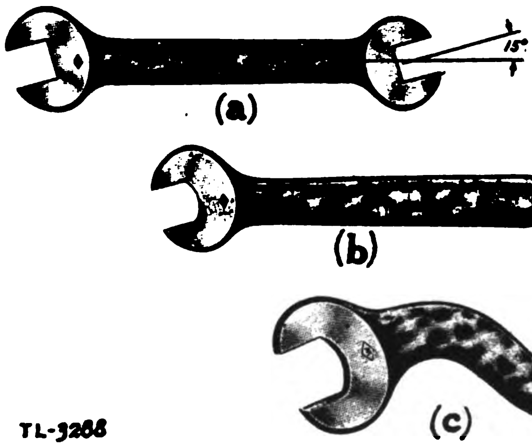

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Figure 6

bolt-heads or nuts. The three types of adjustable wrenches are illustrated in figure 7.

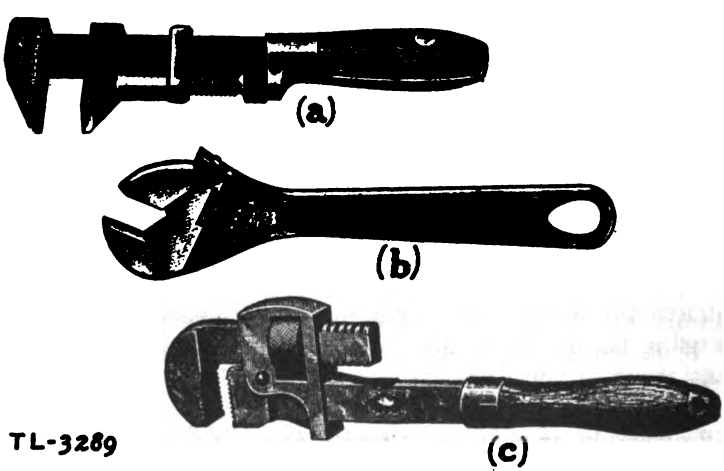

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Figure 7

Socket wrenches.—This type of wrench is usually stronger and more useful than the fixed or adjustable wrenches because they grip all sides of the nut or bolt-head at the same

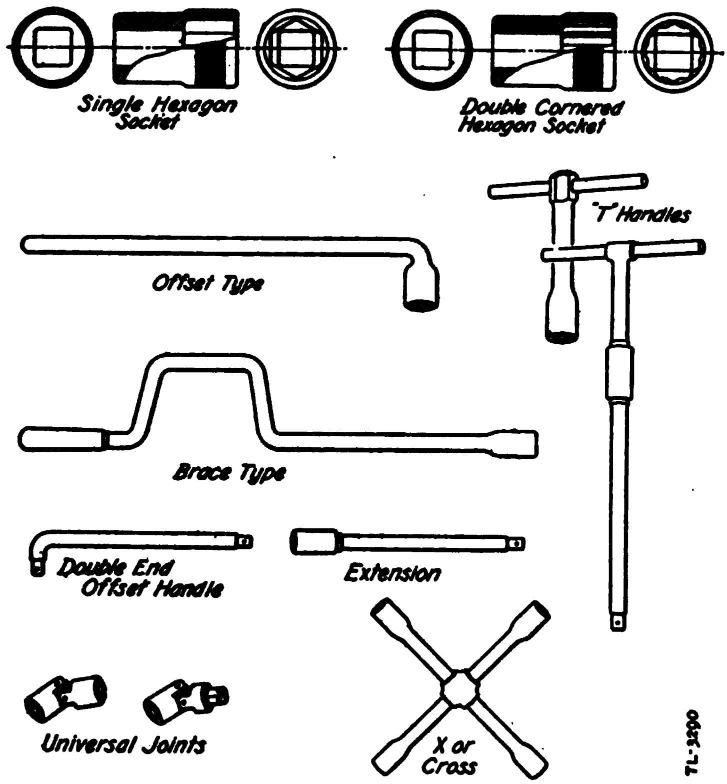

Figure 8

time, which is less likely to cause damage than are the other types of wrenches. The socket wrench is also more efficient for work in close places and for speed of operation. In using the socket wrench it is well to remember that it is possible to apply more force to it than the work can stand. If the user of a socket wrench will bear this fact in mind, he will probably never be faced with the tedious job of removing a screw or bolt with a battered head or sheared off end.

Types of socket wrenches are illustrated in figure 8.

LESSON 7

LABORATORY

Tools and materials.—

2 ea. Splicing clamps (LC-24)
1 ea. Pliers, 8-inch side-cutting
1 ea. Scissors, electrician's
*4 pcs. No. 10 copper wire
*4 pcs. No. 12 galvanized iron wire
*Sleeves, copper No. 10
*Sleeves, tinned steel No. 12
*Emery cloth

Items marked * are not placed on the memorandum receipt.

Operation 1.—Make a Western Union splice, use the No. 10 copper wire.

Make a Western Union splice, use No. 12 galvanized iron wire.

..................................Ins. check

Operation 2.—Make a sleeve splice, use the No. 10 copper wire.

Make a sleeve splice, use the No. 12 galvanized iron wire.

..................................Ins. check

Operation 3.—Practice cutting wires with the electrician's scissors. If the student experiences any difficulty with this operation, the instructor will demonstrate the proper method of using the scissors.

..................................Ins. check

LESSON 8

ROPE, SPLICES, KNOTS AND BLOCKS

1. General information on rope.—

a. Terms used in the manufacture of rope.—

Fibres.—Materials from which yarns are spun.

Strand.—Yarns twisted together.

Rope.—Strands twisted together.

Laying.—The process of twisting strands together in making rope.

b. Terms used in the handling of rope.—

Bight.—A section of the rope turned back on itself.

Turn or loop.—A turn on a rope with the ends extending in opposite directions.

Round turn or bend.—Any turn in a rope around itself or some other object.

Knot.—A combination of bights and turns arranged so the tight part of the rope will bear on the free end of the rope.

Hitch.—Attaching a rope to an object so it may be readily detached.

Half-hitch.—A turn of the rope arranged so a section of the turn will bear on another section of the turn.

Haul.—Pull on a rope.

Running part or fall line.—The free end or that part of the rope that is hauled upon.

Standing part.—The stationary end or that part of the rope that is tight.

Seized.—Two parallel ropes bound together.

Served (whipped).—The end of a rope wrapped to keep the strands from untwisting.

Splice.—Two ropes joined together by interweaving the strands.

Taut.—Hauled tight or under tension.

c. Standard manila rope.—Manila rope is furnished in the following sizes and each size may be obtained in coils up to 1200 feet in length.

TABLE 1

Size, (Diameter in inches)	*Breaking strength, new rope (lbs.)*	*Safe working strength, new rope (lbs.)*	*Weight of rope, (lbs. per ft.)*
¼	700	200	.02
⅜	1450	400	.0417
½	2450	700	.075
⅝	4000	1100	.133
¾	4900	1400	.165
1	8200	2300	.27
1¼	12500	3000	.42
1½	17500	5000	.6

Half the value of the loads specified in this table shall be used if the rope has been in service more than 6 months. New rope loses one-third to one-half of its strength in 6 months of ordinary use. Spliced rope has approximately 80 percent of its orginal strength. Rope is usually sold by the pound. When ordering rope, where this method is used, convert the footage into pounds by multiplying the required number of feet by the number of pounds per foot as given in table 1.

Example: Required 1500 feet of ½-inch. 1500 times .075 equals 112.5 lbs.

d. Uses of manila rope.—In telephone work the rope used will depend on the load and other conditions encountered. Manila rope, preferably dry, should be used where there is a possibility of contact with wires carrying current. If the rope is wet or damp the workmen should wear rubber gloves. If manila rope other than the standard rope is used, examine it carefully, to make sure it does not contain a metallic strand. To do this untwist the strands for a few inches, then untwist the yarns.

e. Selecting the size of rope for the work to be performed.—The approximate weight of the load to be handled must be known, before selection of the proper size rope. After determining the load, and the rigging that is to be used, select a size of rope, whose working strength will not be exceeded by the weight of the load to be applied. If necessary to use blocks, select the simplest rigging to accomplish the work with safety and without loss of time. The size of rope required for use with blocks is determined by the diameter of the sheave groove. A sheave groove with too small a diameter places an excessive bend in the rope, causing the fibres to break. Table 3 shows the proper size ropes for the various size blocks. (See rigging.)

f. Storing rope when not in use.—New rope shall be left in the original coil until required and shall be stored in a dry place, in a manner to provide a circulation of air. Used rope shall be stored in the same manner, after it has been coiled or placed on reels. *Do not store new or used rope unless it is completly dry.* To dry rope hang it up in loose coils on harness hooks or rounded pegs, to permit a free circulation of air around and through the coils. Rope should be dried as soon as practical after it is wet. The drying should be done by placing the rope in the sunshine or in a warm room. Rope, wet or dry, should never be placed over a hot radiator or placed too near a fire.

g. Transporting rope.—When transporting rope in trucks, it shall be hung on brackets provided for this purpose; the floor being kept clear to prevent tripping men, cutting the rope with edged tools, and tangling of rope. Never store or transport rope near a storage battery, as the acid or alkali will seriously injure the rope.

h. Inspection routine.—The man in charge of a construction crew should inspect tackle for faults when it is issued, and at least once, during each week of use. He shall make an inspection of the surface of the rope and blocks for any faults that may have developed. Inspection shall be made once each month for the internal condition of the rope.

The person responsible for the tackle shall at all times assume the responsibility of determining that the ropes and blocks are in good condition, and that their appearance indicates neither deterioration nor injury, sufficient to affect their strength.

i. Inspection of manila rope.—In view of the numerous conditions that may affect the strength and, that only part of the rope may be affected, examination should be made to determine the condition of the rope through its entire length, as explained below. If there is any doubt of the safeness of the rope, it shall be exchanged for rope in good condition. The important things to look for on the surface of the rope are as follows:

(1) Abrasions or broken fibres.—Caused by dragging rope over sharp stones, by kinks or crosses in the rope when under tension, cutting with a sharp tool or by exposure to acids such as the acid used in storage batteries.

(2) Extremely soft.—Caused by overstressing rope, wearing out due to normal life of the rope, or by exposure to any cause that will injure the inner fibres.

When inspecting rope for internal faults, the strands should be separated at 3-foot intervals and the fibres inspected for the following:

(1) Broken fibres.—Caused by working rope through sheaves which are too small, or tying to an object which is too small.

(2) Mildew, mould or fine powder.—Caused by rope not being dried nor cleaned properly after being subjected to mud or sand. The fibres of a rope will change color if it is not properly dried before being stored. Fine powder in rope indicates the presence of grit. To remove grit, the rope should be whipped up and down on a hard surfaced road, after being thoroughly dried.

j. Inspection of blocks.—Blocks should be inspected to determine their condition as suggested below:

(1) Bent, broken or cracked shell.

(2) Cracked or broken sheave.

(3) Cracked or broken becket.
(4) Cracked or broken straps.
(5) Bent hook.
(6) Cotter pin missing.
(7) Roller bushing not functioning.

If any of the above conditions exist and there is any doubt as to the safety of the block, it shall be exchanged for one in good condition.

k. Maintaining blocks in the field.—Keep blocks free of oil and dirt. The sheaves of the standard blocks are roller bushed, and operate better without oil which tends to collect oil and grit, thereby causing the rollers to bind. If the sheaves do not function properly, remove the sheave as outlined below and remove the dirt by tapping the sides of the sheave lightly.

If the hook of a block has started to open, exchange the block, or if a spare hook is available replace the hook. This is done by removing the cotter pin from the sheave pin with pliers. It may sometimes be necessary to oil the pin with kerosene and drive it out with a hammer. After removing the cotter pin, pull out the sheave pin, being very careful not to drop the sheave which will break or scar the edges of the sheave. Pull hook straps out and replace the new hook in position.

l. Coiling and uncoiling rope.—When used rope is not placed on reels, lay out a turn of the desired size and continue the turns in a clockwise direction.

In uncoiling used rope, turn the coil over and draw the end first laid down, from the inverted coil. Be careful not to select the wrong end, if the coil has been tangled or upset.

Remove new rope from coil as explained below; this method retains the rope in its proper form and prevents kinks. See figure 1.

(1) Remove the binding material and secure outside end of rope to an adjacent coil.

(2) Lay the coil on the flat side with the inside end nearest the floor.

(3) Reach down through the coil, grasp the free end of rope and draw out through the top of coil.

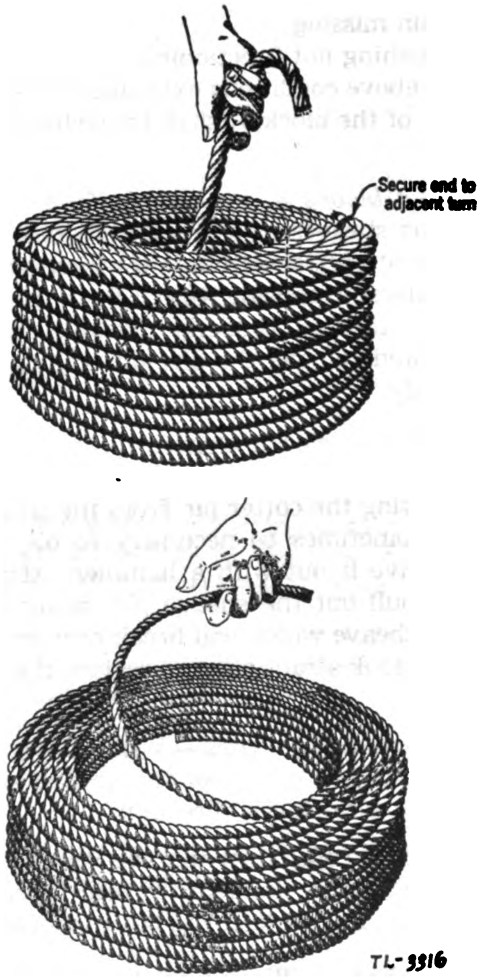

Figure 1

m. Cutting manila rope.—Before cutting rope, wrap several turns of friction tape around the rope on each side of cut, and cut rope with a sharp tool. If it is desired to keep the ends from permanently untwisting, serve or whip them with a strong twine or place a crown splice in the ends.

2. The more common rope splices.—*a. Serving splice (whipping).*—The operations required to serve the ends of a rope are as follows. See figure 2(a).

(1) Unlay one strand of the rope back a little more than one turn, to a point where the serving is to begin. Under this strand lay the twine, leaving the end marked 1, 8 to 10 inches long as shown in 2-*A*. Then relay the strand into the rope, keeping it tightly twisted and held firmly in place.

(2) Let the short end of the twine 1, hang down the rope. Wind the long end of the rope marked 2, around the rope, just above the short end as shown in 2-*B*.

(3) Lay the end of twine 1, along the rope towards its end and there bend it back, thus forming the open bight 3, as shown in 2-*C*, which can be pulled in under the serving when tucking the ends.

(4) Lay the sides of the bight 3, in a groove of the rope. Wind the long end of the twine 2, around the rope and the doubled twine, being careful to pull it up tightly and to leave no open spaces between the turns as shown in 2-*D*.

(5) Continue winding as far as desired, then pass the long end 2 of the twine through the bight 3, as shown in 2-*E*, and pull the long end up firmly. By pulling on the free end 1, of the bight 3, draw the long end of the twine 2, downward underneath the serving, to about the center, *not all the way through.*

(6) Finish the serving by cutting off the two protruding ends of the twine as closely as possible. Cut off excess rope as shown in 2-*F*.

b. Crown splice.—See figure 2(b).

(1) Unlay the rope for 10 to 12 inches and hold it in one hand with the loose ends up as shown in 2-*A*.

(2) Take strand 1 on the left and lay it across the end of the rope between the other two strands as shown in 2-*B*.

(3) Take strand 2 back and down over strand 1 as shown in 2-*C*.

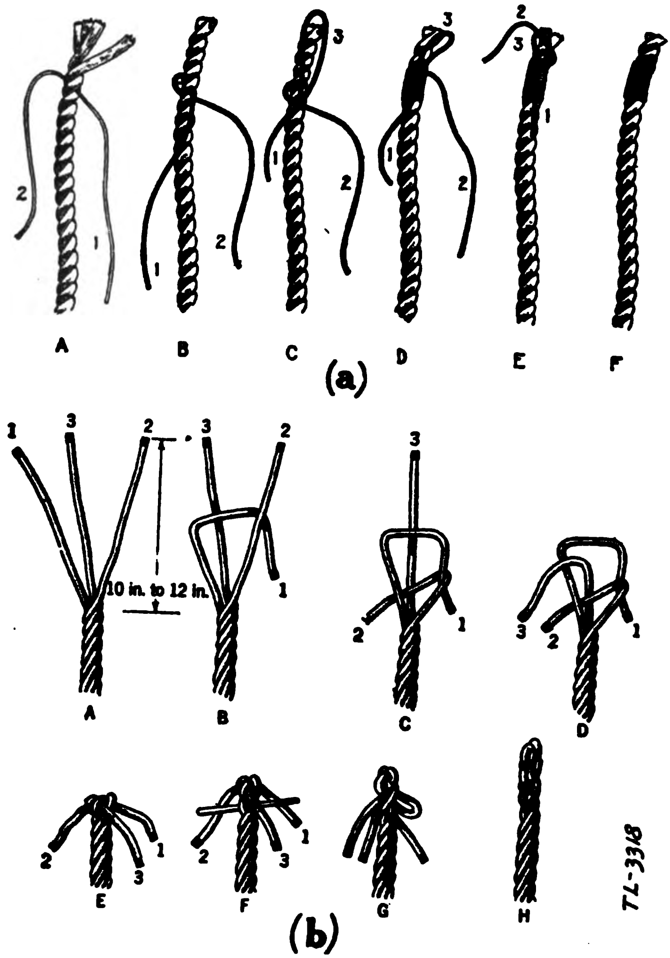

Figure 2

(4) Take strand 3 across 2 through bight in 1 as shown in 2-*D*.

(5) Pull all ends tight as shown in 2-*E*.

(6) Continue tucking each successive strand over the nearest strand and under the next strand of the main rope as shown in 2-*F*.

(7) Tuck until about four complete operations are made.

(8) Roll between two surfaces under pressure, as between foot and floor, to smooth out splice, then cut off surplus ends flush with the outside strands. The completed splice is shown in 2-*H*.

c. Eye splice.—The eye splice is used to form a permanent loop or eye, in the end of the rope. This splice has 90 percent of the strength of a straight rope. When heavy wear will take place on the inside of the eye, it is advisable to splice an oval thimble in the eye. An eye splice is illustrated in figure 3(a).

(1) Untwist the strands of the rope for a length of 10 to 16 inches. Throw a bight into the rope of a size to correspond with the size of the eye required. Select as strand 1 the strand that is on top of the rope and between the other two loose strands as shown in 3-*A*.

(2) Raise a strand on the top of the main rope and tuck 1 under it at right angles, as in 3-*B*, pulling it down securely. Raise the adjoining strand in the main rope and tuck 2 under it as in 3-*B*. Raise the remaining strand in the main rope and tuck 3 through.

(3) When all the ends have been tucked through for the first time, pull them down tight as in 3-*C*. Proceed to interweave the strands as in a short splice.

(4) Roll the splice between two flat surfaces under pressure, as between foot and floor, and trim off surplus ends flush with the outside strands. The completed splice is shown in 3-*D*.

d. Short straight splice.—Short straight splice is used to unite the ends of rope by interweaving strands, and when properly made it has 80 percent of the strength of the rope. See figure 3(b).

(1) Untwist the strands at one end of each rope for a length of 10 to 16 inches. Butt the ends of the rope tightly together as in 3-*A* laying the strands of each rope alternately between the strands of the other rope; that is, strand 1, is between 2 and 4; strand 3, is between 4 and 6, and strand 5, is between 2 and 6. This process is called locking the strand.

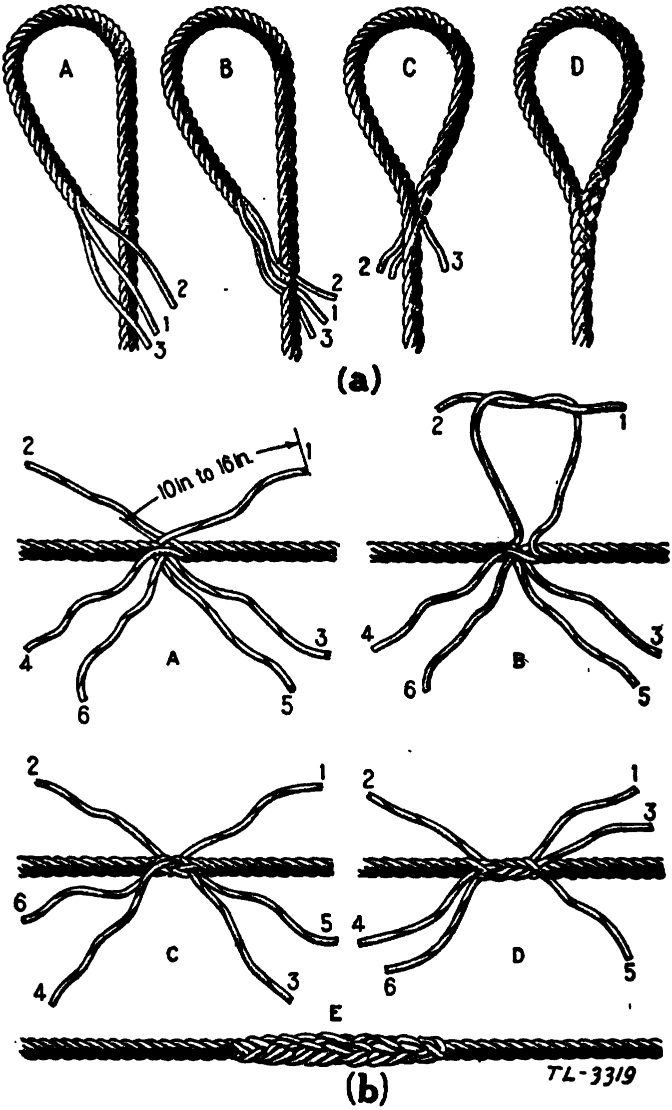

Figure 3

(2) Tie each strand of one rope to the corresponding strand of the other rope with a regular overhand knot as

1 and 2, of 3-*B*. Complete tying, 3 to 4, and 5 to 6, in a similar manner.

(3) Pull all knots down tight as in 3-*C*.

(4) Carry each end over the adjacent strand of the rope and tuck it under the next strand. Start with and proceed to strand 6, in progressive order. This will produce an arrangement as in 3-*D*. Repeat this operation until the total length of the interweaving strands extends through a distance of 4 inches, for one-quarter inch rope, and add an additional tuck for each next largest standard size rope.

(5) Roll splice between two flat surfaces under pressure, as between foot and floor, and trim off the surplus ends flush with the outside strands. The completed splice is shown in 3-*E*.

e. Long straight splice.—The long straight splice is used to unite the ends of rope required for passing over sheaves, by interweaving strands, and when properly made it has 90 percent of the strength of the rope and therefore it is stronger than the short straight splice. Figures 4 and 5 illustrate, in sequence, the steps in making the long straight splice. The advantages of this splice are; stronger than the short straight splice, and smaller than the short straight splice, thereby allowing it to pass through the sheaves of a block.

(1) Unlay only one strand of each rope for 10 or 12 turns. Lock and draw ends of the rope tightly together, having the single strands 1 and 2 side by side, as illustrated in figure 4.

(2) Taking care not to let the ends of the ropes separate, unlay strand 1 from its rope one turn, and follow it with strand 2. Keep 2 twisted up tightly and pulled down firmly into its place. Continue this procedure until only 6 to 9 inches of strand 2 is left out; depending on the size of the rope.

(3) Untwist the two pairs of strands left at the center and lock them as shown in figure 4. Strand 3 between strands 4 and 6, and strand 6 between strands 3 and 5. Unlay toward the left, strand 4 and follow it with strand 3, as was done

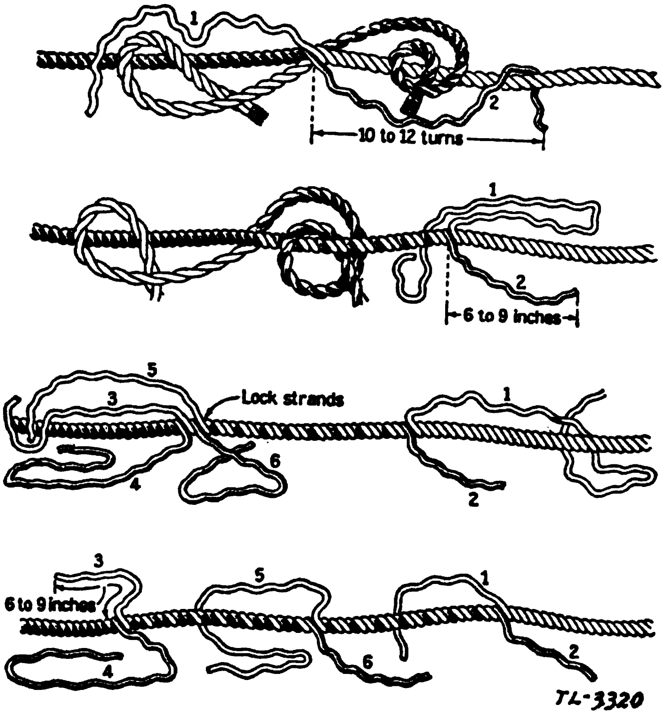

Figure 4

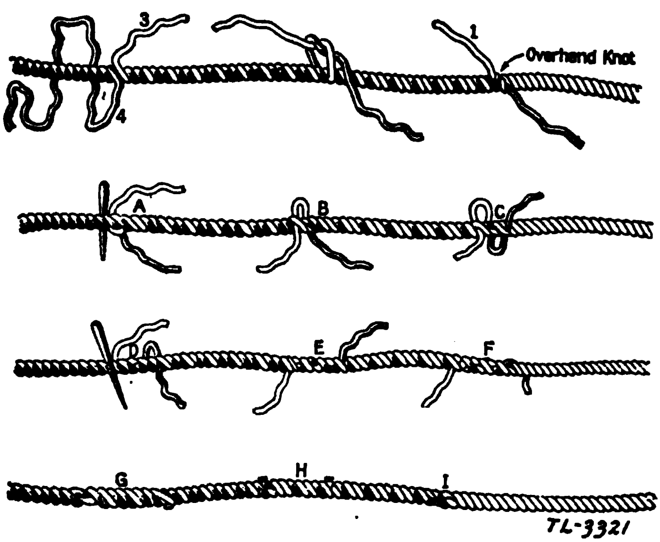

Figure 5

toward the right with strands 1 and 2. *Note.—Do not unlay strand 6 instead of 4 and follow it with 3.*

(4) Continue until strand 3 is only 6 to 9 inches long. The breaks in the strand are now separated as shown in figure 4.

(5) Each pair of strands is tied together now, and the end of each strand tucked. Cut all strands the length of the shortest, that is, 6 to 9 inches long. Arrange each pair so that the strand from the left is in front of the strand from the right; or, in other words, arrange the strands so that they cannot untwist from the rope without first uncrossing. Tie each pair of strands together with an overhand knot and pull down tightly into rope as shown in figure 5.

(6) Tuck each strand as shown in figure 5.

(7) Tuck each strand twice more, tapering the ends if desired, and cut the end ½ inch long.

(8) With a round stick pound down each part of the splice and roll it between two flat surfaces under pressure, as between foot and floor. The completed splice is shown in figure 5.

3. The more common knots, bends and hitches used in teleplone work.—The strength of manila rope containing a knot is reduced about 60 percent, as the bend in the rope places most of the strain on the outside fibres.

a. Figure eight knot.—This knot is used to prevent the end of a fall line from running through the blocks. See figure 6(a). Throw a turn into the rope leaving sufficient end to complete the knot, then pass the end around the rope and through the bight. Draw all parts down tight.

b. Block becket bend.—This knot is used when attaching a rope to the eye of a guy rod or to the becket of a block, where a temporary connection is desired. See figure 6(b).

(1) Pass the rope around the thimble on the becket of a block as shown in 6-*A*.

(2) Take a turn around the standing part outside of the bight as illustrated in 6-*B*.

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(3) Take a second turn around the standing part through the bight, forming two half-hitches in reverse as shown in 6-*C*.

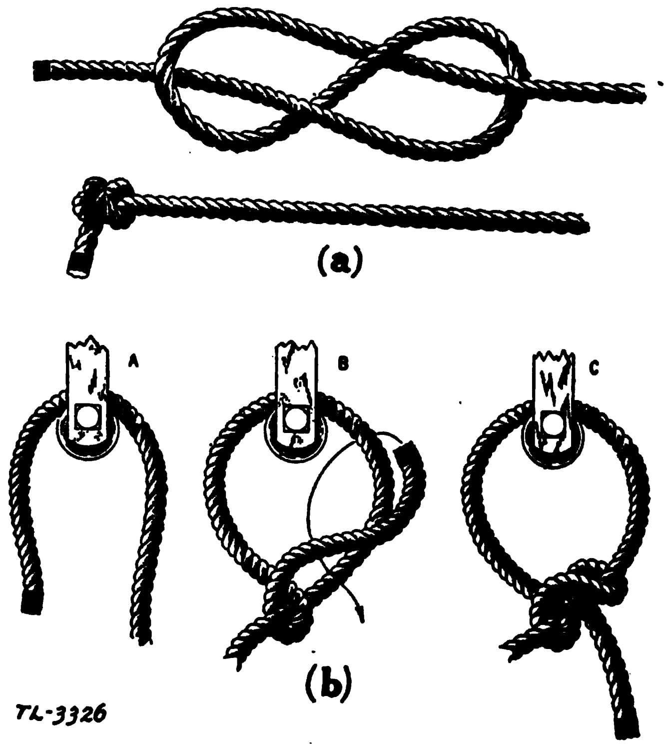

Figure 6

c. Square knot.—This knot is used in uniting the ends of the same size ropes, that may be placed under strain. A square knot, joining two ropes of unequal size is very apt to slip. Figure 7 illustrates a square knot.

(1) Cross the ends of the rope, placing the right under the left as in figure 7-*A*.

(2) Bend each rope back on itself as shown in 7-*B*.

(3) Wrap end marked 1, around the end marked 2, away from you as shown in 7-*C*.

(4) Pull all parts down tight. The completed knot is shown in 7-*D*.

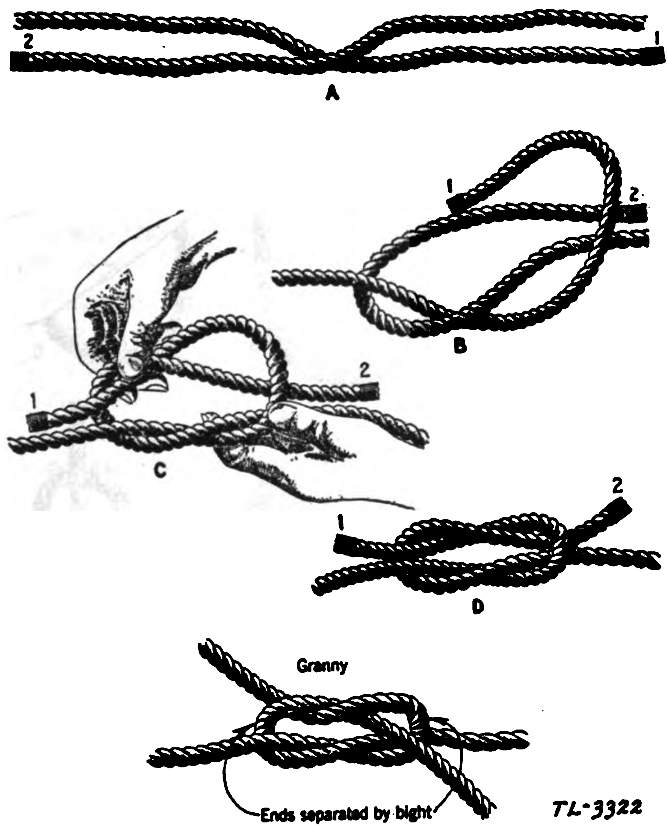

Figure 7

A *granny knot* is shown in figure 7, so that it may be readily identified and avoided.

d. Bowline knots, general.—The bowline knots are used in making hitches of all types and are formed in various ways, depending upon the conditions encountered. It is a tie of universal use, and is the best known method for forming a bight that will not slip under tension and is easily untied.

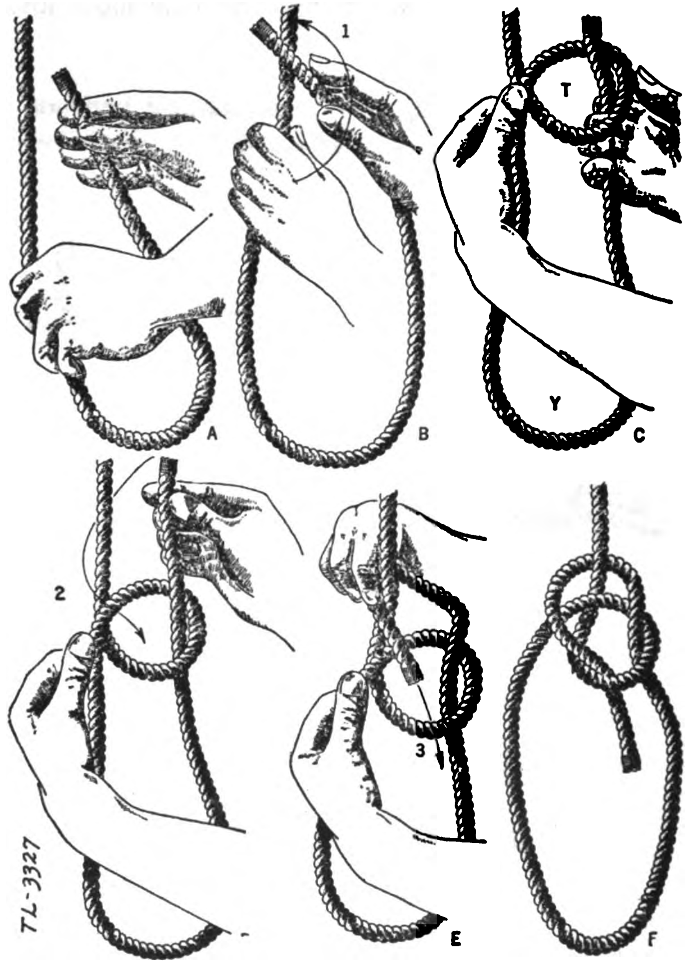

Figure 8

e. Single bowline at the end of a rope, not attached to an object.—This knot is used for attaching a rope to the hook of a block or joining the ends of ropes of different sizes. See figure 8.

(1) Grasp the standing part of the rope with the left hand, at a point where the turn *T* is desired. This position is determined from the size of the bight *Y*, required. Hold the free end in the right hand.

(2) Move the right hand forward and lay the free end across the standing part of the rope, above the left hand, with sufficient end to complete the subsequent turns. Hold the right hand stationary and bring the left hand upward and forward as indicated by the arrow 1.

(3) Just as the left hand is passing the right, turn the right hand palm up, which will result in the formation of a loop in the standing part of the rope, with the end of the rope projecting up through it.

(4) Grasp the free end with the right hand and move it forward.

(5) Pass the free end around and behind the standing part of the rope from right to left, as indicated by the arrow 2, then pass the free end forward and down into the turn again, from above, as indicated by the arrow 3.

(6) Draw all parts down tight. The completed knot is shown in figure 8-*F*.

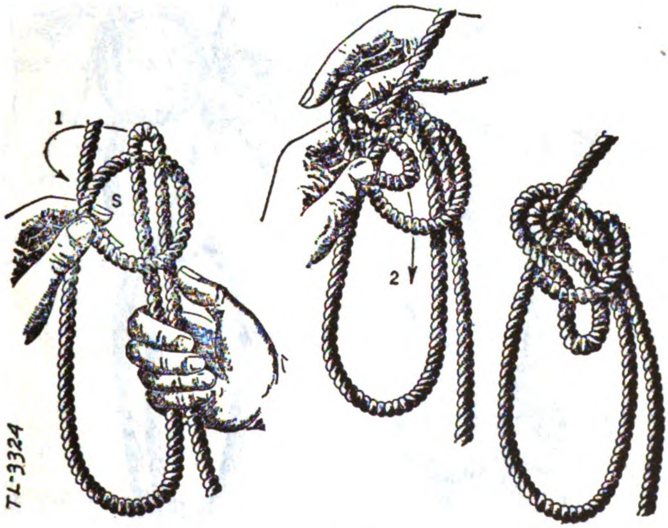

Figure 9

f. Single intermediate bowline.—This knot is used to attach the rope to the hook of a block, where the end of the rope is not readily available. See figure 9.

(1) The operations required in making this knot are identical with the single bowline, not attached to an object, with one exception; that is, in step *(D)* the part with which the knot is completed is not a free end but a part of the rope doubled back in a bight.

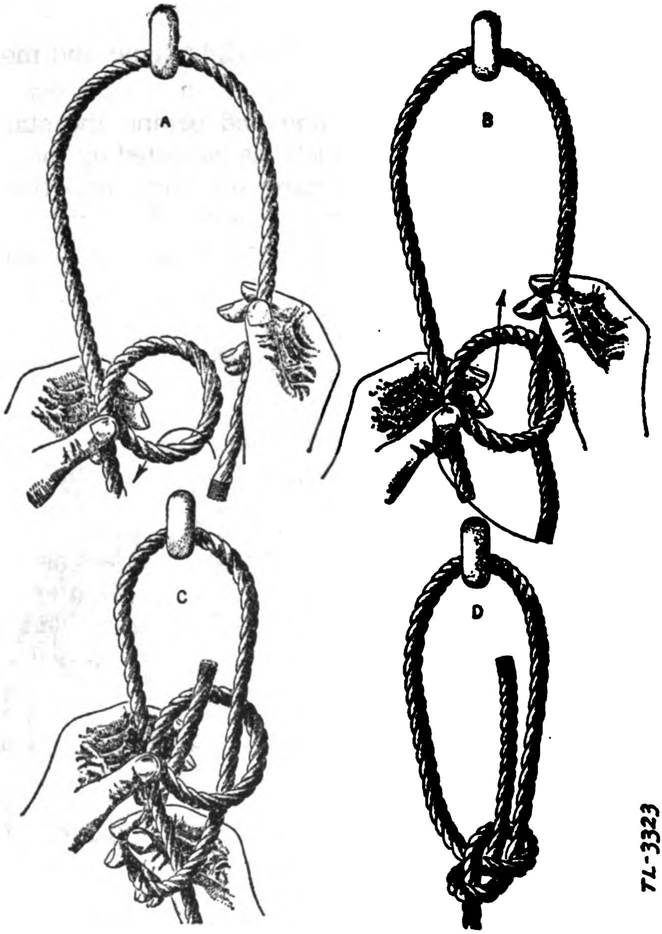

Figure 10

g. Single bowline, at the end of a rope, attached to an object.—This knot is for tying a bowline through a ring or eye. See figure 10.

(1) Throw a turn into the rope, leaving sufficient end to complete the knot, then pass the free end through the eye or around the object, holding the standing part with the turn in the left hand as shown in 10-*A*.

(2) Pass the free end through the turn in the standing part of the rope as illustrated in 10-*B*.

(3) Bring the free end from right to left, over the standing part of the rope and turn it under, passing the end through the turn as shown in 10-*C*.

(4) Draw all parts down tight. The completed knot is shown in figure 10-*D*.

h. Double bowline.—This knot is used in tying at intermediate points, and allows two ropes to pass through the eye or point of strain, thereby doubling the strength at the point of greatest stress. See figure 11.

(1) The operations required to make this knot are identical with the operations of the single bowline, at the end of a rope, attached to an object.

i. Double bowline on a bight.—This knot is used as a semipermanent eye in the middle or end of a rope, to engage a hook, clevis or some other similar fastening. This knot allows two ropes to pass through the fastening. See figure 12.

(1) Double the rope and throw a turn into it leaving sufficient end to complete the knot as shown in 12-*A*.

(2) Pass the end through the turn, as explained for a single type bowline, until the position shown at *Z*, is reached as shown in 12-*B*.

(3) Turn the bight *S*, down over the front and then up in back of turn *Y* as shown in 12-*C*.

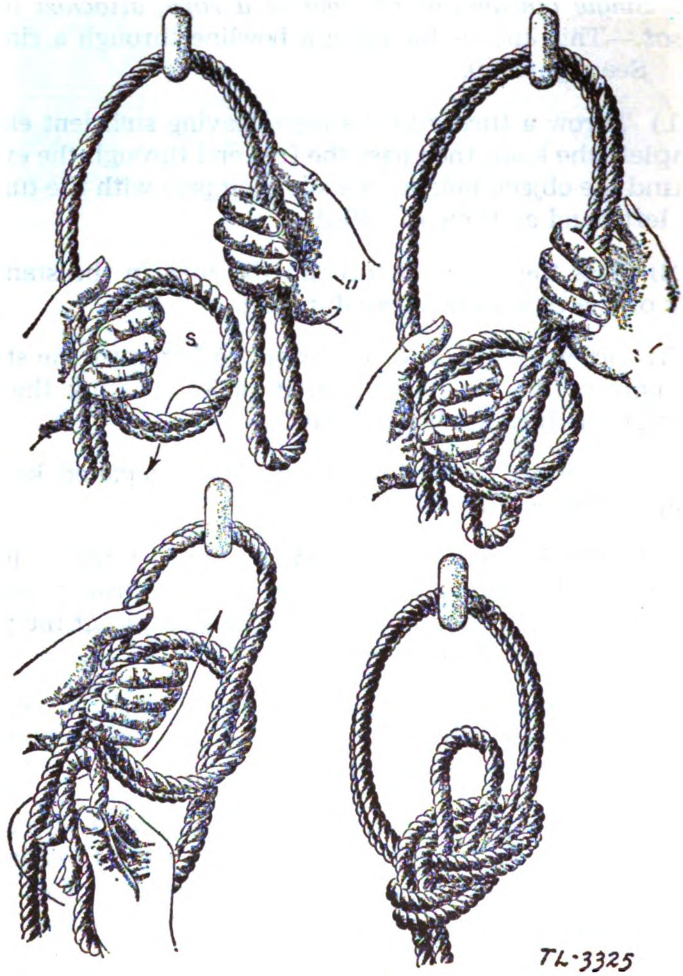

Figure 11

(4) Pull all parts down tight. The completed knot is shown in 12-*D*.

j. Clove hitch.—The clove hitch is used in attaching tools and materials to a hand line. It may also be used in guying gin poles, when the tension is equally divided along the guy ropes in opposite directions. This hitch will stand a stress in either direction when properly set. It is quickly made and

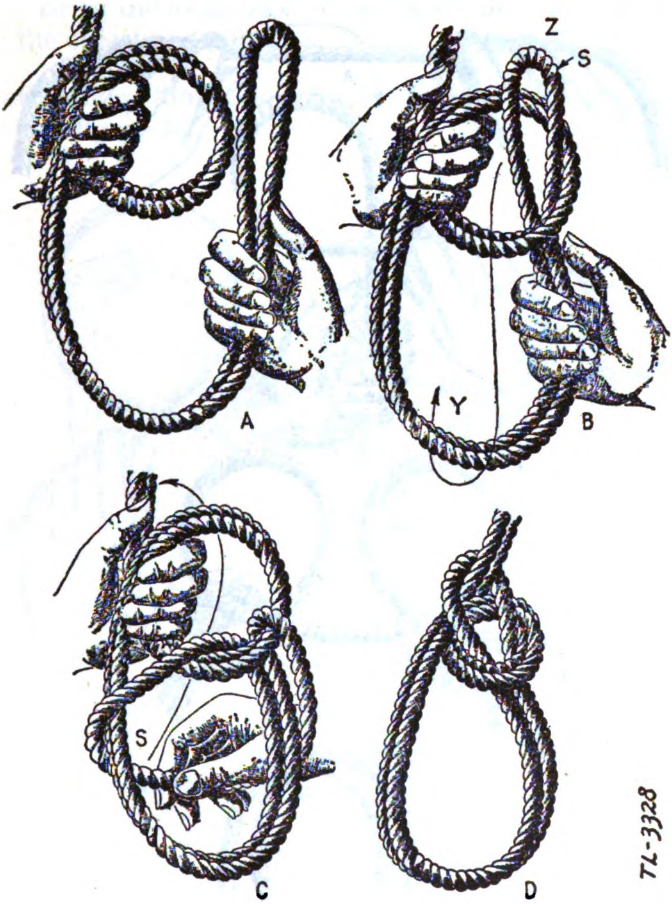

Figure 12

easily undone. The clove hitch is compossed of two half-hitches made either at the end of a rope or in the middle without access to the ends. It can be made in a number of ways, three of which are explained and illustrated in figure 13, 14 and 15.

Method of making a clove hitch to pass over low objects, such as a stub pole or stakes. See figure 13.

(1) Hold the rope as shown in 13-*A*.

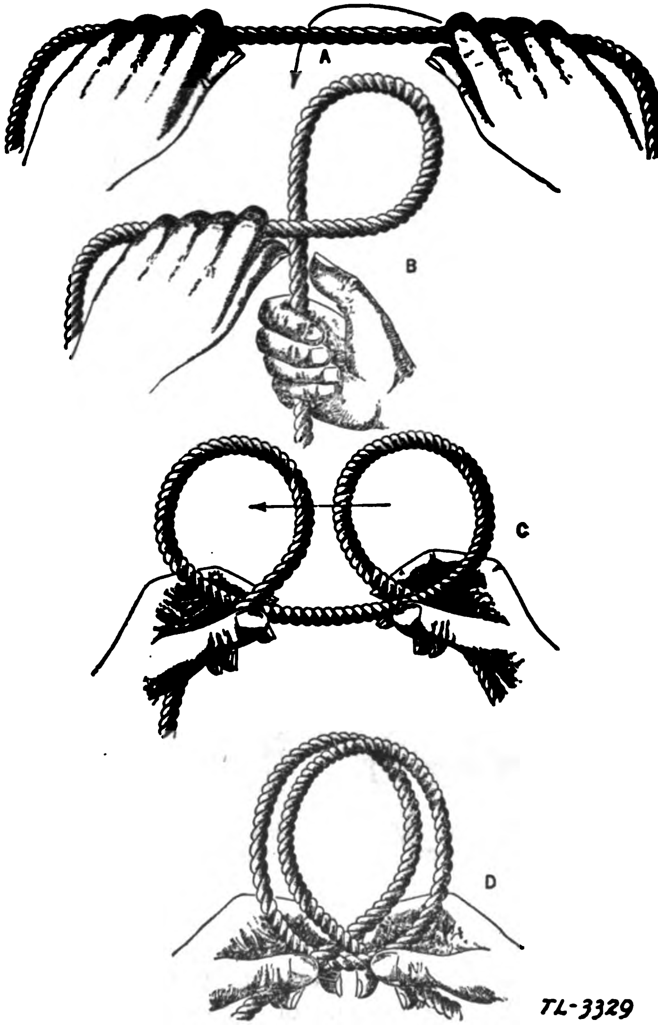

Figure 13

(2) Twist the rope held in the right hand to form a loop, shown in 13-*B*.

(3) Hold this loop with the left hand and throw a second loop with the right hand in the same manner, shown in 13-*C*.

(4) Bring the loops together as shown in 13-*D*, then place over the object and pull taut.

Method of making a clove hitch when there is a pull on the rope. See figure 14.

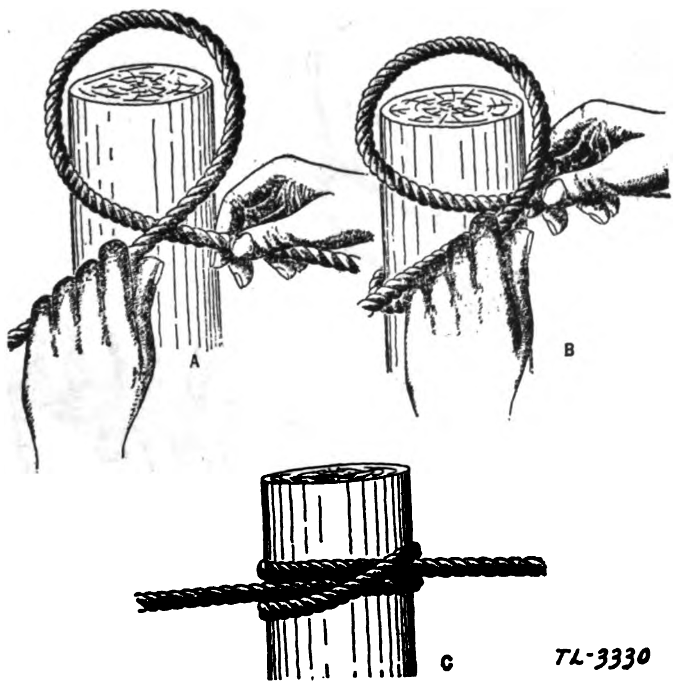

Figure 14

(1) Hold the strain on the rope with the left hand and twist the rope to the right, with the right hand, to form a loop in the rope, and then roll the loop over the top of the post. Shown in 14-*A*.

(2) Move the left hand up beyond the loop, hold the rope there and with the right hand form a second loop, roll it in place and pull taut.

(3) The completed knot, in place, is shown in 14-*C*.

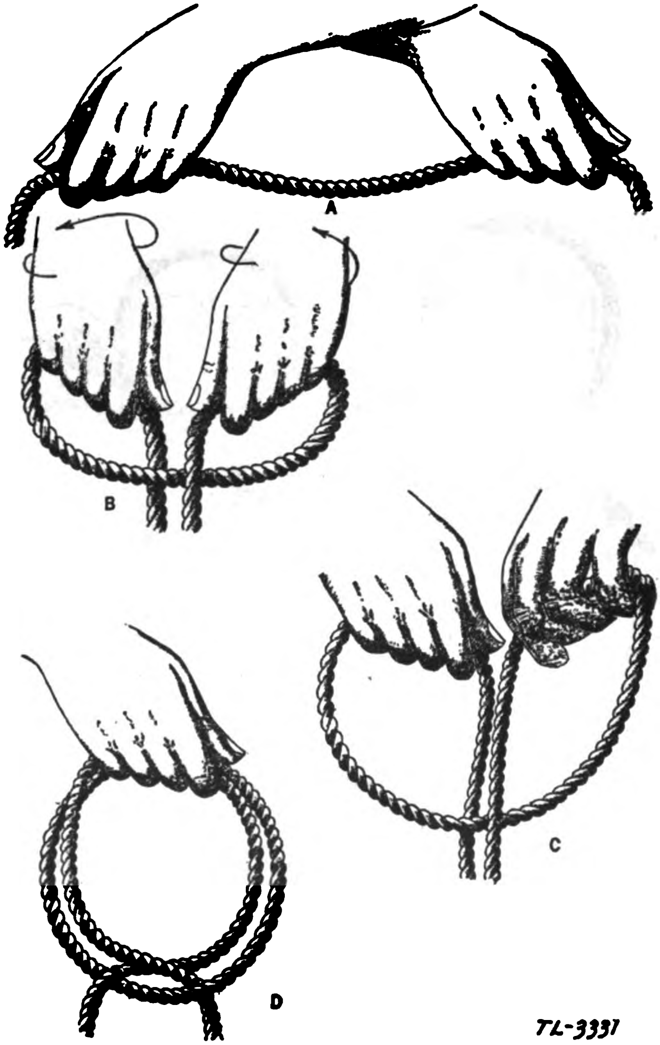

Figure 15

The quickest method of making a clove hitch is shown in figure 15.

(1) Cross the arms in front of the body, with the left arm outside the right and pick up the rope as shown in 15-*A*.

(2) Without twisting the wrists, uncross the arms. Shown in 15-*B*.

(3) Now rotate both hands to the right, as indicated by the arrows around the wrists, shown in 15-*B*, and put the knuckles of the left hand into the palm of the right hand.

(4) Slip the loop from the left hand into the right hand, and the hitch is ready to pass over the object. Shown in 15-*D*.

k. Snubbing hitch.—This knot is used for securing temporary guys to poles and trees. See figure 16.

(1) Pass the rope around the pole or object twice, then turn the free end around the standing part inside the bight. Shown in 16-*A*.

(2) Take another turn inside the bight as shown in 16-*A*.

(3) Complete the hitch with two half-hitches as shown in 16-*B* and 16-*C*.

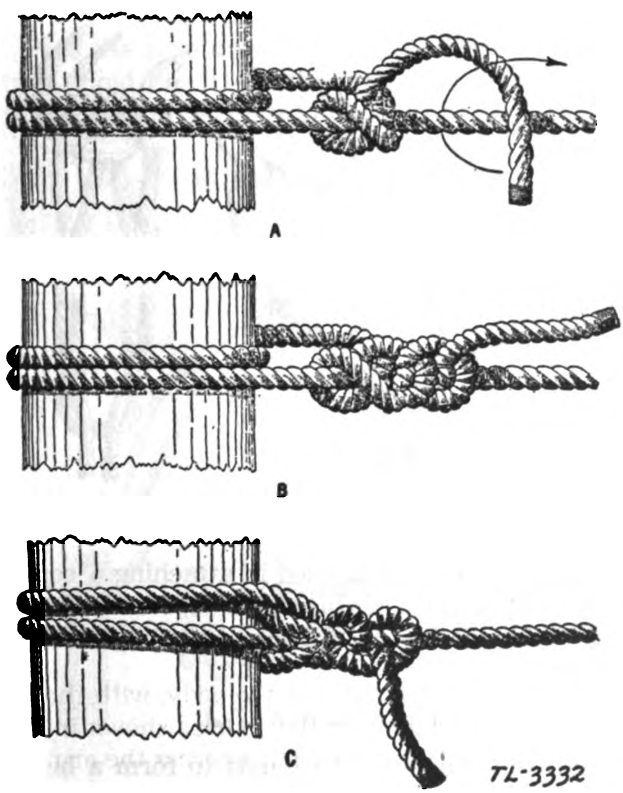

Figure 16

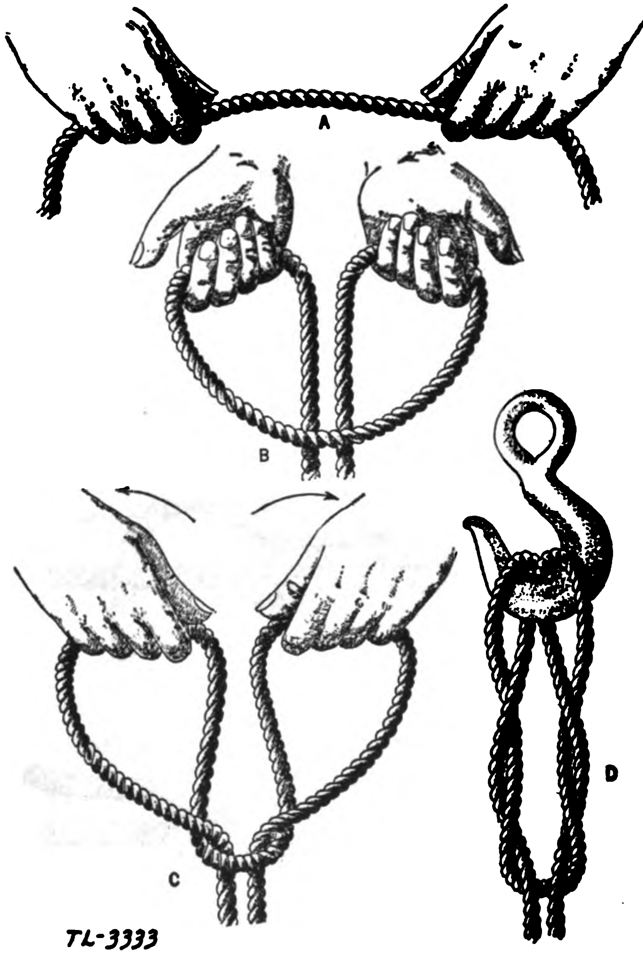

Figure 17

l. Catspaw.—This knot is used in attaching a rope to the hook of a block. It provides a double rope over the hook of the block and permits a load to be carried on either end of the rope. See figure 17.

(1) Grasp the rope as shown in 17-*A*.

(2) Drop rope between the hands to form a bight, then twist the hands, thus forming two loops as shown in 17-*B*.

(3) Twist each loop a half turn in the direction indicated by the arrows in 17-*C*.

(4) Twist each loop another half turn and hang loop on the hook. The completed hitch is shown in 17-*D*.

m. Platform guy knot.—This knot is used in securing the ropes, leading from the splicers platform to the pole, ladders, and other supports. See figure 18.

(1) Select the side of the platform from which the splicer is to work. Grasp loose end of guy rope from opposite side of the platform and pass it around the pole, about 3 feet from the ground and pull tight. Keep the guy rope clear of steps and avoid blocking the climbing space.

(2) Take a turn over and around the standing part of the rope with the loose end, and pull to the desired tension.

(3) Pass the rope around the pole so that it crosses the first turn. Hold the free end of the rope in this position to snub pull on the platform. Pull to the desired tension.

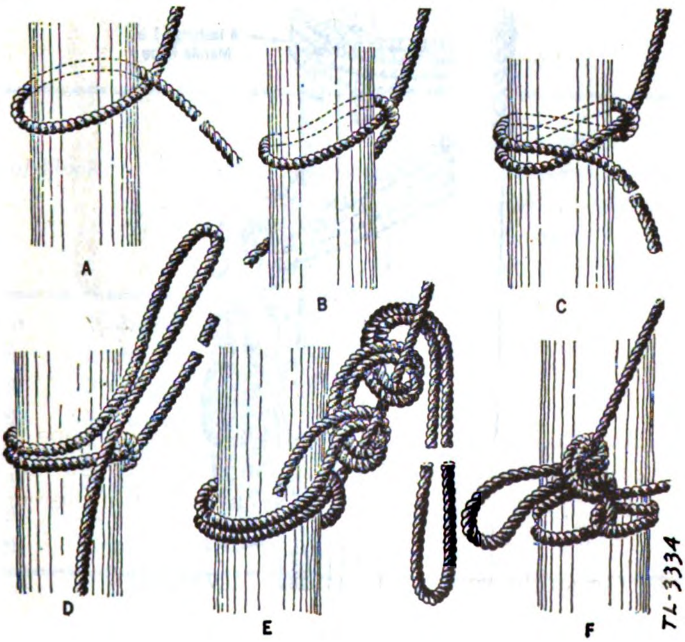

Figure 18

(4) If the free end is too long to handle, double the rope as shown in 18-*D*.

(5) Secure with two half-hitches on the standing rope. The completed knot is shown in 18-*F*.

(6) The other guy rope shall be secured on the same side of the pole, near the turns of the first guy rope. Since this guy leads from the opposite direction, it must necessarily be snubbed in the opposite direction.

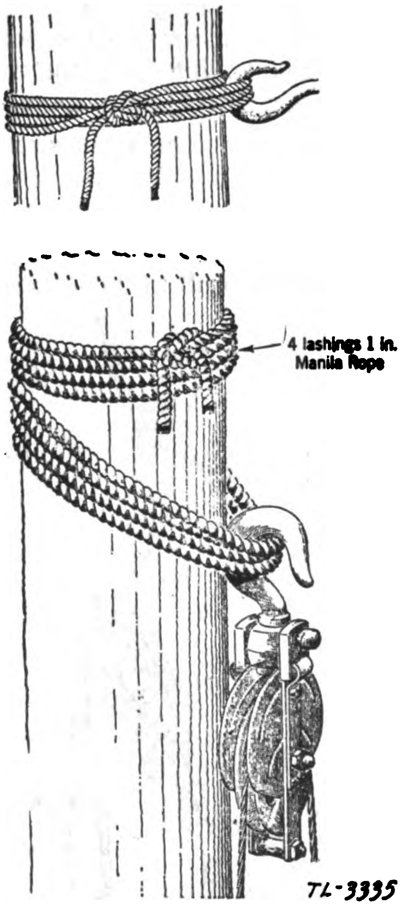

Figure 19

n. Lashing.—Lashings are used when a temporary attachment is desired. The ease of attaching and detaching and the safety factor, will determine the type of lashings that will be used in various conditions. Lashings to be used where the pull is perpendicular to the axis of the pole and where the pull is parallel to the axis of the pole are shown in figure 19.

The rope used for lashing should be of the size shown in table 2, and in good condition. Rope which has been discarded as unsafe for pulling line or for use in blocks, should not be used for lashings. When lashing a block to a pole, the number of turns around the pole shall be the same as the number of turns through the hook.

TABLE 2

Size of block		*Size of rope lashings Required number of turns through hooks of blocks for the following sizes of rope*			
		⅜	½	⅝ or ¾	1 (inches)
3 inch	1 sheave	2			
3 inch	2 sheave	3	2		
3 inch	3 sheave	4	3		
4 inch	3 sheave		4	3	
6 inch	3 sheave			4	3
8 inch	3 sheave				4
6 inch	Snatch			4	3
8 inch	Snatch				4

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Figure 20 shows the type of lashing to be used when lashing two poles together. Figure 20 also shows the lashing used in securing a ladder to a messenger. A ladder should not be moved after it has been lashed to the messenger.

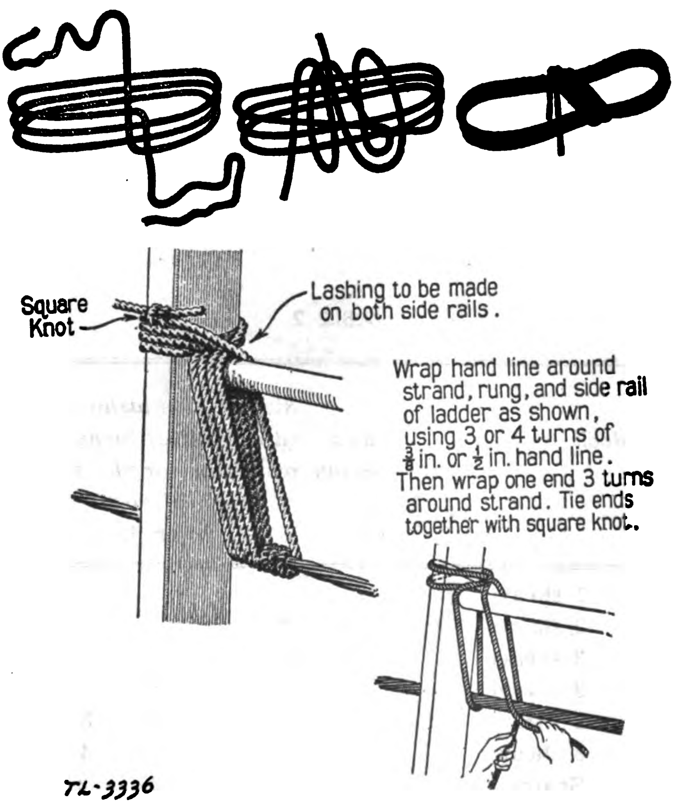


Figure 20

4. Blocks.—*a. General.*—The parts of a block are the shell, sheave, hook, becket, becket bolt, bushing, cotter pin, center strap, outside strap and roller bushing. See figure 21 (a).

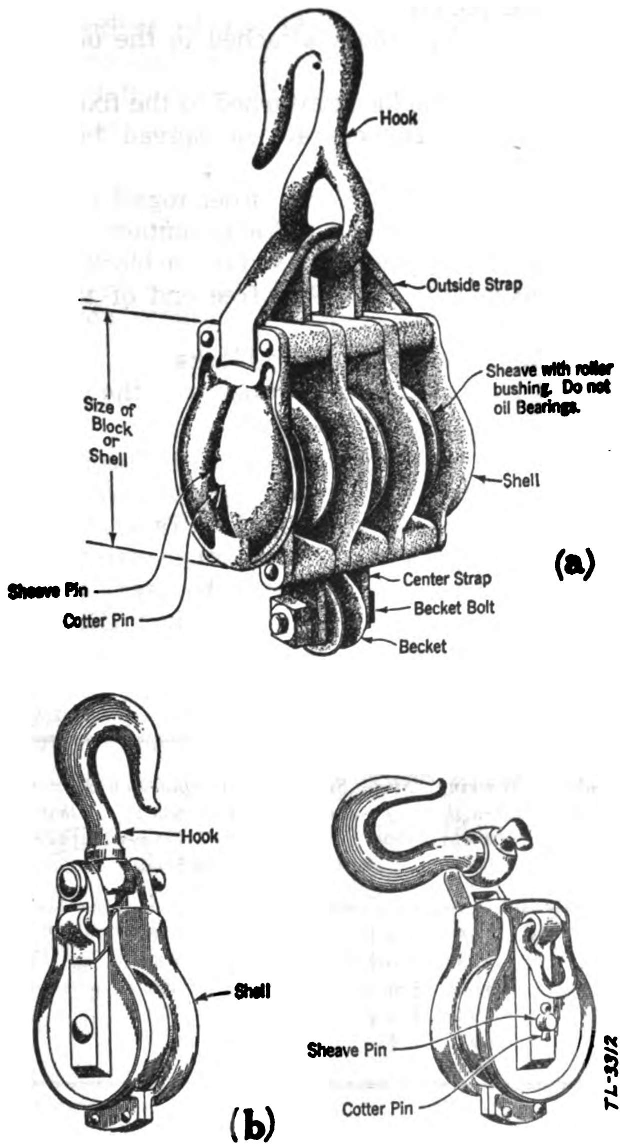


Figure 21

The terms commonly used in reference to blocks are as follows:

Tackle.—An assembly of ropes and blocks. The rope is commonly called the fall.

Running block.—The block attached to the object to be moved.

Standing block.—The block attached to the fixed support.

Overhaul blocks.—To separate or spread blocks in a tackle.

Run in block.—To bring blocks closer together.

Chock-a-block.—Blocks of a tackle in contact.

Standing end.—End of a rope fixed to the block.

Running end or fall line.—The free end of the rope in tackle.

Return.—The rope between two blocks.

Reeving of blocks.—To pass rope over the sheaves of blocks to obtain mechanical advantage.

b. Standard blocks.—Standard blocks are furnished in the sizes as shown in table 3, and are equipped with the open type hook unless ordered with shackle. Table 3 shows the standard sizes and types of blocks, together with their working strength and the size of rope to be used. The size of blocks is determined by the length of their shell and the number of sheaves.

TABLE 3

Size of blocks	*Number of sheaves*	*Working strength of hooks (lbs.)* *	*Size of rope* **	*Suggested length (ft)*	*Maximum load that may be applied to new small rope*	*Maximum load that may be applied to new large rope*
3 inch	1	2100	3/8 or 1/2	50	400	700
3 inch	2	2300	3/8 or 1/2	75	400	600
3 inch	3	3900	3/8 or 1/2	100	400	650
4 inch	3	4600	1/2 or 5/8	150	700	800
6 inch	3	8600	3/4	200	1400	......
8 inch	3	12000	1	275	2300	......

* Maximum load permitted on hooks.

** The smaller size rope shall be used, in general, where the weather conditions are humid.

The hooks of the standard and snatch blocks have been designed so that they start to open at approximately 70 percent of the maximum load they will carry, thus acting as a visible safety link to warn against overstressing, before complete failure of the block. To obtain the maximum strength, the load should be applied at the lowest point of curvature of the hook. The maximum working strength of the hooks, as given in table 3, is based on the load being applied at the lowest point of curvature of the hook. It is impracticable to give the strengths of the hooks for all conditions, as the load may not always be applied in the same manner. When blocks are in use, the hook should be under observation at all times, to determine if the hook has the required strength to withstand the applied load.

c. *Manila rope snatch blocks.*—Snatch blocks are furnished in two sizes: 6-inch or 8-inch. The hooks have a working strength of 11,000 pounds and 17,000 pounds respectively. This working strength is approximately 70 percent of the maximum load they will carry. The 6-inch block is intended for use with $\frac{5}{8}$- or $\frac{3}{4}$-inch manila rope and the 8-inch block is intended for use with 1- or $1\frac{1}{4}$-inch manila rope. Snatch blocks are illustrated in figure 21(b).

d. *Reeving of blocks.*—It is important that blocks be reeved properly to have them operate to the best advantage and avoid jamming, which would lose time and possibly cause an accident. The 2- or 3-sheave blocks shall be reeved in either of the ways as shown in figures 22 and 23.

When reeving with new rope, place the rope under slight tension. The fall line should emerge from the center sheave of a 3-sheave block. This causes the hoisting strain to come on the center of the block, preventing it from turning and cutting the rope on the block shell. When reeving by this method, figure 22, the sheaves of the two blocks should be placed at right angles to each other.

Where there is a possibility of the rope being tangled, when reeving by the method shown in figure 22, the blocks may be reeved left over right, as shown in figure 23.

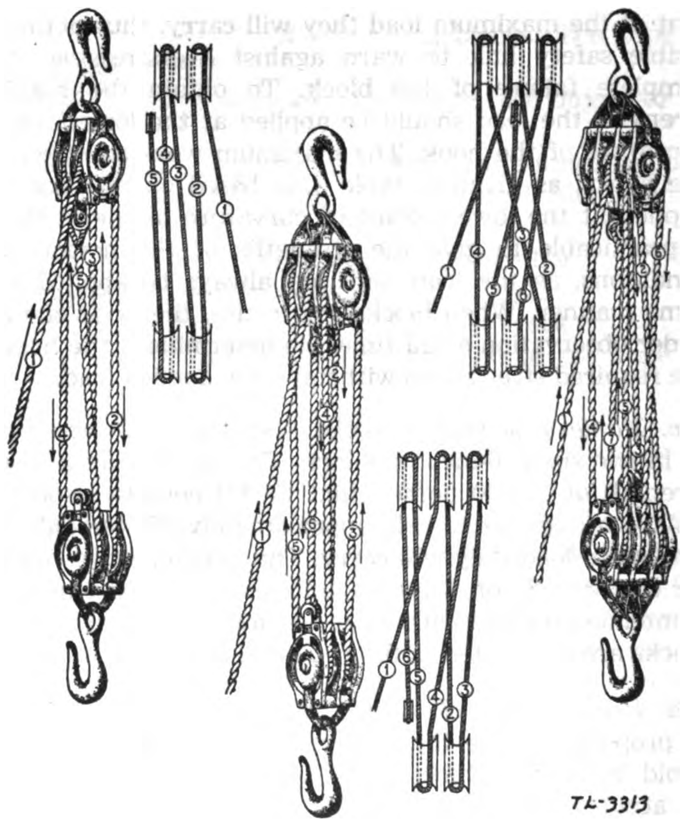


Figure 22

e. Rigging.—The type of rigging used will depend upon the weight to be handled and the available motive power. The simplest rigging, that will adequately perform the work, should be selected. Luffing tackle is a commonly used type of rigging. A simple definition of luffing tackle is; additional tackle (blocks and necessary rope), attached to the fall line of the main tackle (tackle attached to the load). Figure 24 shows luffing tackle used two different ways, lifting a load and hauling a load.

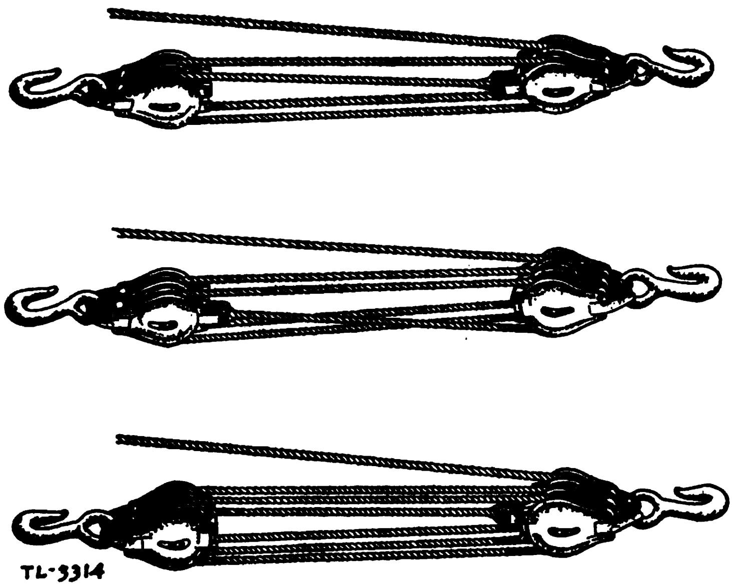
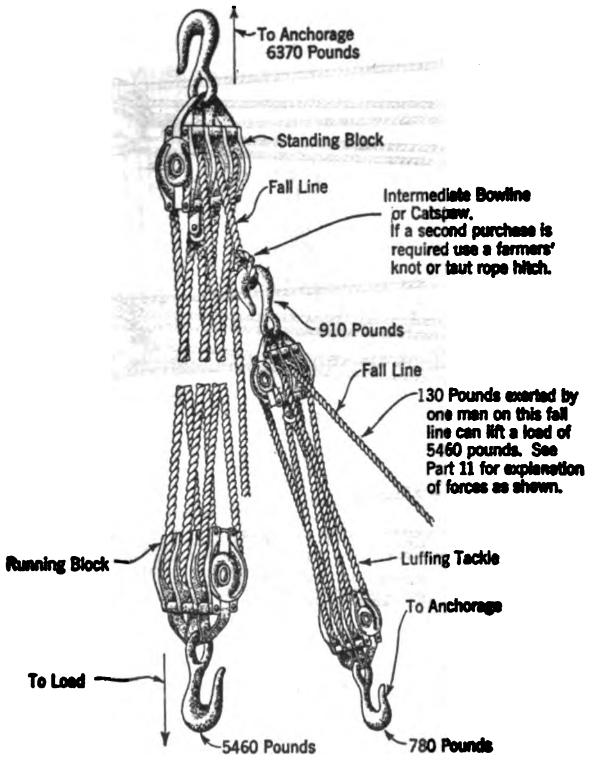


Figure 23

When the load to be handled is greater than can be handled safely by the workmen, then block and tackle shall be used to gain a mechanical advantage. For practical purposes, the weight capable of being lifted is equal to the applied force times the number of ropes leaving the movable block. For example, if a man can exert a force of 130 pounds on the fall line of a three sheave tackle, he will be able to lift 6 times 130 or 780 pounds. This assumes the fall line leaves the fixed block, as in lifting a load, figure 24. If the fall line leaves the movable block as in hauling a load, figure 24, the same man can lift 7 times 130 or 910 pounds.

LIFTING A LOAD



HAULING A LOAD

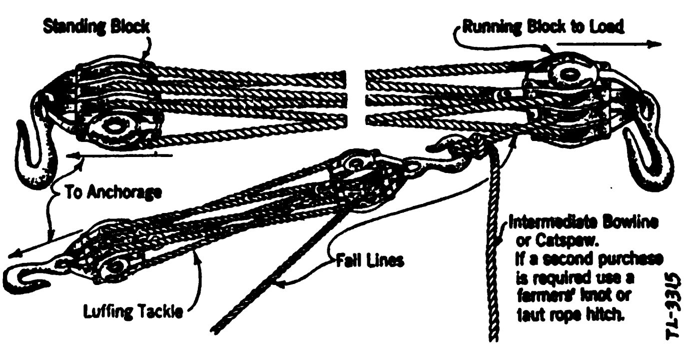


Figure 24

f. Selecting the proper size blocks for the work to be performed.—To do this it is necessary to know the approximate weight to be handled, the motive or lifting power available and the strength of the hooks of the standard blocks. Knowing the load and the available power, calculate the number of sheaves required, by dividing the load by two times the power. If this result is three or less, select one of the standard blocks with the number of sheaves as calculated and a hook strong enough to withstand the load. If this result is over three, it will be necessary to select a system of rigging from the standard blocks available. This rigging will require luffing tackle, which in general is a 3-sheave arrangement. See figure 24. When using luffing tackle, remember that for practicable purposes, the stress in the fall line of the tackle attached to the load, is equal to the force applied to the fall line of the luffing tackle, times the number of ropes leaving the movable block of the luffing tackle, which will be six or seven.

To determine the number of sheaves required in the tackle attached to the load, divide the load to be lifted by twice the applied power. Select a block with a hook capable of withstanding the load. Be sure that the load applied to the fall line of the tackle attached to the load, is not too great for the size of the rope as specified in table 1.

Example: Refer to figure 24, (lifting a load). 5460 pounds to be lifted by one man who can exert a force of 130 pounds.

To find the number of sheaves required 5460/2 x 130 equals 20 (approximate).

The number of sheaves required is greater than three, therefore luffing tackle is required. Three-sheave blocks will be used in the tackle attached to the load, with the fall line leaving the fixed block, which makes the man capable of lifting 6 times 130 or 780 pounds.

Number of sheaves required in luffing tackle 5460/2 x 780 equals 2 plus. (use 3)

Using 3-sheave blocks in the luffing tackle, the fall line leaving the moving block, the man can lift 7 times 130 or 910 pounds.

With a 910 pound pull exerted on the fall line of the main tackle (by use of the luffing tackle), the man will be able to lift 6 times 910 or 5460 pounds.

When the approximate weight and motive power is known, the proper size blocks can be selected from table 3, in most cases.

5. **Safety precautions.**—Safety to life and property requires that rope and blocks be well cared for. A few precautions, in addition to those previously listed in the text are given below:

(1) A hook that has begun to straighten shall be discarded immediately.

(2) Do not use blocks with sheave holes too small to give clearance, between the sheaves and the sides and top of the shell.

(3) When moving from one location to another, do not drag rope on the ground.

(4) Do not stand unnecessarily close to, and never straddle rope under tension.

(5) Do not stand in the inside angle, or in the path of rope being paid out or under tension.

(6) Do not use frozen rope.

(7) The hand line shall not be attached to the belt, when working on poles. Make it fast to the crossarm or to the pole.

(8) Hand line or other rope secured aloft, when not in use, shall be secured at a point near the ground to prevent it from being blown about.

(9) Rope shall be placed as to create no obstruction on highways or thoroughfares, unless unavoidable; in that case, place a man to warn traffic.

(10) Gloves should be worn when handling new rope to avoid the possibility of injury from fibre slivers.

Review questions.—

1. Name the various parts of a block.

2. How are the sizes of blocks determined?

3. What is the weakest part of the block?

4. In what way does a snatch block differ from other blocks?

5. What is the process of threading rope through blocks called?

6. What is the fall end of rope?

7. What is the term applied to a set of blocks, attached to the fall line of the main tackle?

8. What should blocks be inspected for, to determine their condition?

9. How and where should rope be stored?

10. How should new rope be removed from the original coil?

11. What should be done to rope before it is cut?

12. What is the purpose of a serving and a crown splice?

13. What two advantages does the long straight splice have over the short straight splice?

14. What is the eye splice used for?

15. What are the two great advantages of the bowline?

16. What is the block becket bend used for?

17. What is the snubbing hitch used for?

18. What knot is used for securing the guy ropes of cable splicers platforms?

19. What are lashings?

20. Should the bearings be oiled on a sheave equipped with roller bushings?

LESSON 8

LABORATORY

Tools and materials.—

1 ea. Knife TL-19
*Rope for reeving, knot tying, splicing.
*Friction tape, lacing twine.
Items marked * are not placed on the memorandum receipt.

Do not cut the reeving nor the knot tying ropes.

Blocks for reeving will be found in the class room.

Operation 1.—Inspect the blocks selected and list the faults below.

..................................Ins. check

Operation 2.—Reeve the two 3-sheave blocks as shown in figure 22.

..................................Ins. check

Operation 3.—Reeve the 3-sheave and the 2-sheave block as shown in figure 22.

..................................Ins. check

Operation 4.—Reeve the two 2-sheave blocks as shown in figure 22.

..................................Ins. check

Operation 5.—Using short pieces of rope make the following: a serving splice, a crown splice, an eye splice and a short straight splice. Submit to the instructor.

..................................Ins. check

Operation 6.—Practice tying the following knots: the figure 8 knot, the square knot, single bowline, intermediate bowline, double bowline, bowline on a bight, block becket bend, clove hitch, snubbing hitch, catspaw, and platform guy knot. These knots should be learned well enough so that the student can tie any of them from memory when called upon to do so by the instructor.

..................................Ins. check

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TM 11-454

WAR DEPARTMENT

TECHNICAL MANUAL

THE RADIO OPERATOR

April 21, 1942

TECHNICAL MANUAL No. 11-454

WAR DEPARTMENT, WASHINGTON, April 21, 1942.

THE RADIO OPERATOR

*This edition of TM 11-454 includes C1, June 25, 1941, and C2, January 19, 1942.

SECTION I

GENERAL

1. Purpose.—The purpose of this manual is to provide a text for the training of radio operators and to establish an authoritative basis for coordination between all units of the Army in the use of radio procedure in the conduct of radio communication. Since operators of manual field telegraph equipment, signal lamp equipment, and wigwag flags also employ the International Morse Code and applicable portions of radio procedure, this text is suitable for the instruction of those operators also.

2. Scope.—This manual covers the selection of personnel which will probably absorb instruction most quickly, the basic instruction of all operators, and radio procedure in tactical and other nets. While the bulk of the content is devoted to the radiotelegraph operator, such instruction as is considered essential for the radiotelephone operator is also included. Typewriting instruction is covered only to the extent of showing how it fits into basic operator instruction. Such material as is included can be given effectively with other instruction without appreciable loss of time. The ability to use a typewriter increases the value of an operator, and this fact should be emphasized when code instruction is initiated.

3. Basic radio procedure.—*a.* The radio procedure prescribed herein is for use in radio communication within the Army.

b. Intercommunication between the Army and the Navy is conducted as prescribed in FM 24-10.

SECTION II

SELECTION OF PERSONNEL

4. General.—Because of the relatively great length of time required to train radio operators, the prior determination of the aptitude of students is essential. Consequently, within the limitations of available equipment, all personnel to be trained as operators will be selected as indicated in paragraphs 5, 6, and 7.

5. Radiotelegraph operator aptitude test, U. S. Army.—*a.* This test, heretofore known as the Signal Corps Code Aptitude Test,

has been used for many years by schools and units of all arms and may be considered a standard test. It is designed to determine the aptitude of an individual for learning the International Morse Code phonically by requiring him to indicate whether or not certain tone signals sound exactly alike.

b. A complete test, consisting of an answer sheet, the test, and a solution sheet, is included in appendix I. The test may be given manually with the use of organizational equipment, but is given preferably by phonographic transcription. Phonographic transcriptions for use with code transmitter and recorder TG-8-A, or disk phonograph records which may be played directly on any standard phonograph, are available.

c. The nature of the test makes it difficult for anyone to memorize correct answers. However, available copies of the test and of the solution, as well as all phonographic transcriptions, will be safeguarded to the extent necessary to assure that no person to be tested has had an opportunity to study the test before taking it.

6. Testing.—*a.* The aptitude test is given in about 20 minutes and can be taken simultaneously by as many men as the receiving equipment will permit. Having decided upon the number of men to be trained, give the test to double that number. One copy of the answer sheet is required for each man to be tested. Allow sufficient time prior to the start of the test for men to comply with the directions indicated on page 1 of the answer sheet.

b. When giving the test manually, speak those portions of the test shown in quotation marks and transmit by means of a telegraph key and tone source, the characters shown in parentheses. Transmit all characters at a speed corresponding to 20 words per minute of normal transmission, but allow a time interval of approximately 2 seconds between paired characters. Where test characters are overscored, transmit them as a continuous character without pause between them. Thus, transmit $(\overline{\mathrm{AJ}})$ as . — . — — — not as . — . — — —

c. When the test is given by means of phonographic transcription, set the code transmitter and recorder or the phonograph at a speed corresponding to 20 words per minute of normal transmission. Monitor the transcription of the test to insure that satisfactory transmission is being accomplished. When the transcription consists of two or more disks, change disks promptly at the proper time.

7. Selecting students.—The test is objectively scored; that is, the person scoring the test needs no knowledge of its subject matter in order to score it properly. The final score is determined by deducting one point for each unmarked or incorrectly marked test pair.

Thus, with every pair correctly marked, a maximum score of 78 is obtained. With 16 pairs unmarked or incorrectly marked, the score is 62. The test of each man is scored in about 2 minutes. After scoring the tests, tabulate scores and select students as follows:

a. Place each test paper in one of the following groups:

(1) Those which show that the man tested has had previous experience, however slight, in radiotelegraph or telegraph operation.

(2) Those which show that the man tested has had no previous experience in radiotelegraph or telegraph operation.

b. From each group list the name of each man, followed by his score, in order from the highest to the lowest score.

c. Select the proper number of men to be trained in the order listed below, taking all men from the first category before taking any from the next, and so on.

(1) Those in group *a*(1) above with scores of 60 or higher.

(2) Those in group *a*(2) above with scores of 60 or higher.

(3) Those in group *a*(1) above with scores of 50 or higher.

(4) Those in group *a*(2) above with scores of 50 or higher.

d. If a sufficient number of men are not obtained from the first group, follow the same procedure with another group of prospective students.

e. If, after testing all available men, a sufficient number in the first four categories cannot be obtained, select those with scores of 40 or higher, and then those with scores lower than 40. The former may be expected to become operators only after long training, but in general, instruction of the latter is not productive.

f. Do not inform any student of his score while he is undergoing instruction.

Section III

BASIC INSTRUCTION

8. International Morse Code.—In the International Morse Code, all letters, numerals, and punctuation marks are represented by short and long signals. A short signal is called a dot and is printed as . and a long signal is called a dash and is printed as —. These signals may be transmitted visually as flashes of a lamp for short and long periods or as positions of a flag to the right and left of the flagman. They may also be transmitted phonically, as by a buzzer making short and long sounds or by a telegraph sounder making two successive different sounds with short and long intervals of time between successive sounds. Finally, they may be recorded as transmitted on a tape and read therefrom, by eye, as short and long inked lines. Figure 1 is a full-size sample of receiving tape. This manual is concerned primarily with the instruction of students in recording dot and dash

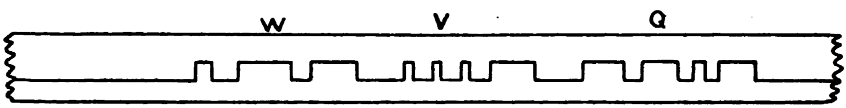

FIGURE 1.—Tape-recorded code characters.

characters as received by ear, and in transmitting similar signals by means of manually operated telegraph keys.

9. Mental processes.—The whole process of receiving consists of recognizing combinations of short and long sounds and recording the characters they represent.

a. Recognizing sounds.—(1) The short and long sounds in each character could be memorized and the characters identified by counting the sounds of each length and noting their arrangement. This process is limited to a very slow receiving speed of about 50 characters per minute.

(2) A better method is to recognize the sound of a complete character without regard to its components.

(3) In order to keep the student from following the faulty mental process in (1) above, experience has shown that it is better to begin by teaching the sound of the character when it is made at a speed used in normal operation, which is about 100 complete characters per minute, corresponding to about 20 words or groups of five characters each per minute. Such a speed discourages the counting of separate dots and dashes. Consequently, in all instruction, individual characters are transmitted at a speed corresponding to 20 groups of five characters each per minute. The speed of transmission is increased by shortening the silent periods (spaces) between successive characters. The longer spaces afford the beginner more time to identify each character. With practice, this thinking process becomes faster and

faster until the student recognizes the characters without conscious mental effort, just as he recognizes words in conversation.

b. Recording the characters.— Characters are recorded by the typewriter or by lettering as prescribed in FM 24-5. Instruction in lettering is given concurrently with that in *a* above, and performance in both is graded. When a student has attained a receiving speed of about ten groups of five characters each per minute, instruction in recording by typewriter may be initiated.

(1) *Lettering.*—In order to insure legibility and thus prevent errors, the prescribed lettering is used. To assist in the grading of lettering, a board may be prepared and kept exhibited to students showing various degrees of excellence in lettering the same message. Examples may be arranged in order from the best to the poorest which is to be accepted as satisfactory. All performance is graded accordingly, and deficiencies are pointed out to the student.

(2) *Typewriter.*—The touch system of typewriting is taught by arranging characters in each lesson so as to cause the recording of characters by certain fingers. Thus, the sound of a character is mentally connected with the action of a specific finger, and an operator while training, simultaneously becomes a touch typist of sounds heard. With a little additional practice he can readily become proficient also as a touch typist in transcribing written or dictated material.

10. Instruction periods.—*a. Duration.*—The duration of an instruction period should not exceed 1 hour, and such a period should be followed by one or more similar periods of instruction which does not require close mental effort. (See par. 11.)

b. Frequency.—Two or more code instruction periods may be scheduled daily, but a total of more than three hours per day is not desirable. However, if periods cover such varied matters as receiving, transmitting, procedure, etc., and if the allotted training time is short, productive instruction may be given for as much as 6 hours daily.

c. Relaxation.—One or two 5-minute periods of relaxation during an instruction period are desirable for maintaining mental alertness.

11. Sequence of instruction.—Code instruction is given in the sequence indicated below concurrently with instruction in the operation of authorized unit equipment. Each operator in a unit should be capable of operating any set with which the unit is equipped. Consequently, instruction in the various sets, including nomenclature, composition, methods of installing, methods of transporting, characteristics, and technical design, together with such fundamental electrical studies as are necessary, should begin when the code course starts. The periods of code and operating instruction are alternated at the discretion of the instructor:

a. Initial reception of five groups per minute.—Initially, separate periods are devoted to each of the five lessons given in paragraphs 14 to 18, inclusive, and in that order. These lessons contain the letters of the alphabet and the numerals. Transmission is at the rate of five groups (25 characters) per minute, and in each lesson the characters of that lesson are transmitted in random order. As soon as the student is able to receive 50 consecutive characters (10 groups) of lesson No. 1 without error, lettering them satisfactorily, he is advanced to lesson No. 2. He is similarly advanced to lessons Nos. 3, 4, and 5. As soon as he has completed lesson No. 5 in this manner, all the letters and numerals are transmitted at the same rate in random order. He qualifies at five groups per minute when he is able to receive 50 consecutive characters (10 groups) without error, recording them satisfactorily.

b. Reception of seven groups per minute and initial transmission.—After the student has qualified as prescribed in *a* above—

(1) The rate of transmission is increased to seven groups per minute. He qualifies at this rate when he is able to receive 70 consecutive characters (14 groups) without error, lettering them satisfactorily.

(2) Instruction in transmission is begun. From this point approximately one-third to one-half of the student's instruction time is devoted to transmitting, with the object of bringing his transmitting speed to at least eight groups per minute by the time he has qualified in reception at the rate of 12 groups per minute. Thereafter, approximately one-third of his time is devoted to transmitting. If the equipment is available, the student is required to transmit to an instrument which records his transmission and reproduces it later. He then is required to receive his own transmission as it is reproduced before he is considered to have qualified at that transmitting speed. He is required to transmit for 2 minutes, and the number of consecutive groups transmitted correctly during that period (as indicated by the student's received copy), divided by 2, is his transmitting speed in groups per minute. If the reproducing equipment is not available, the student is required to transmit to an experienced instructor, who grades the transmission for accuracy, proper spacing, correct manner of transmitting, and speed.

c. Reception of ten groups per minute.—After the student has qualified as prescribed in *b*(1) above, the rate of transmission is increased to ten groups per minute. He qualifies at this rate when he is able to receive 100 consecutive characters (20 groups) without error, lettering them satisfactorily.

d. Recording by typewriter.—After the student has qualified as prescribed in *c* above, and if he is to be instructed in recording by

typewriter, he is returned to lesson No. 1 and repeats the instructions indicated in *a*, *b*, and *c* above, except that all recording is accomplished on the typewriter. At the outset of this instruction he should be furnished an instruction book on the care and use of the machine and a copy of the keyboard chart as shown in figure 2.

e. Subsequent reception.—When the student has qualified as prescribed in *c* above—

(1) All transmissions to him are in the form of messages or procedure signals, and he is required to record them on the prescribed message form. If the student is being trained to record reception by typewriter, he receives the bulk of his instruction in that manner, but is given one period daily in which he is required to record by lettering. For code speeds under 20 words per minute, the student is advanced only when he is able to record properly by both printing and typing. For code speeds above 20 words per minute, reception recording is exclusively by typewriter.

(2) The rate of transmission is increased successively to 12, 15, 20, 25, 30, and 35 groups per minute. When the student is able to receive three consecutive messages averaging 12 groups each without error at any rate, recording them satisfactorily, he is permitted to advance to the next higher rate.

12. Suggestions for instructors.—If a copy of this manual is not available for each student, furnish each man with a copy of the suggestions indicated below at the beginning of his instruction and a copy of each of the lessons given in paragraphs 14 to 18, inclusive, at the beginning of his instruction in each of those lessons. When instruction in transmission is begun, furnish the student with a copy of paragraph 19, and a copy of each of the exercises given in paragraphs 20 and 21 at the beginning of his instruction in those exercises.

13. Suggestions for students.—*a.* Try to recognize the sound of the entire character and to ignore the number of dots and dashes that make it up.

b. Letter the characters exactly as shown in each lesson. Practice lettering until it requires no conscious effort when receiving.

c. Work hard, but if after a while you feel so tired that you are not learning or you become disgusted, lean back, relax, and think of something else for a few minutes in order to restore your mental alertness.

d. Never look back over your copy while you are receiving.

e. If you do not recognize a character immediately, skip it, write down a small dash in place of it, and go on to the next. You will eventually realize what sound combinations you do not recognize and can then give special attention to them.

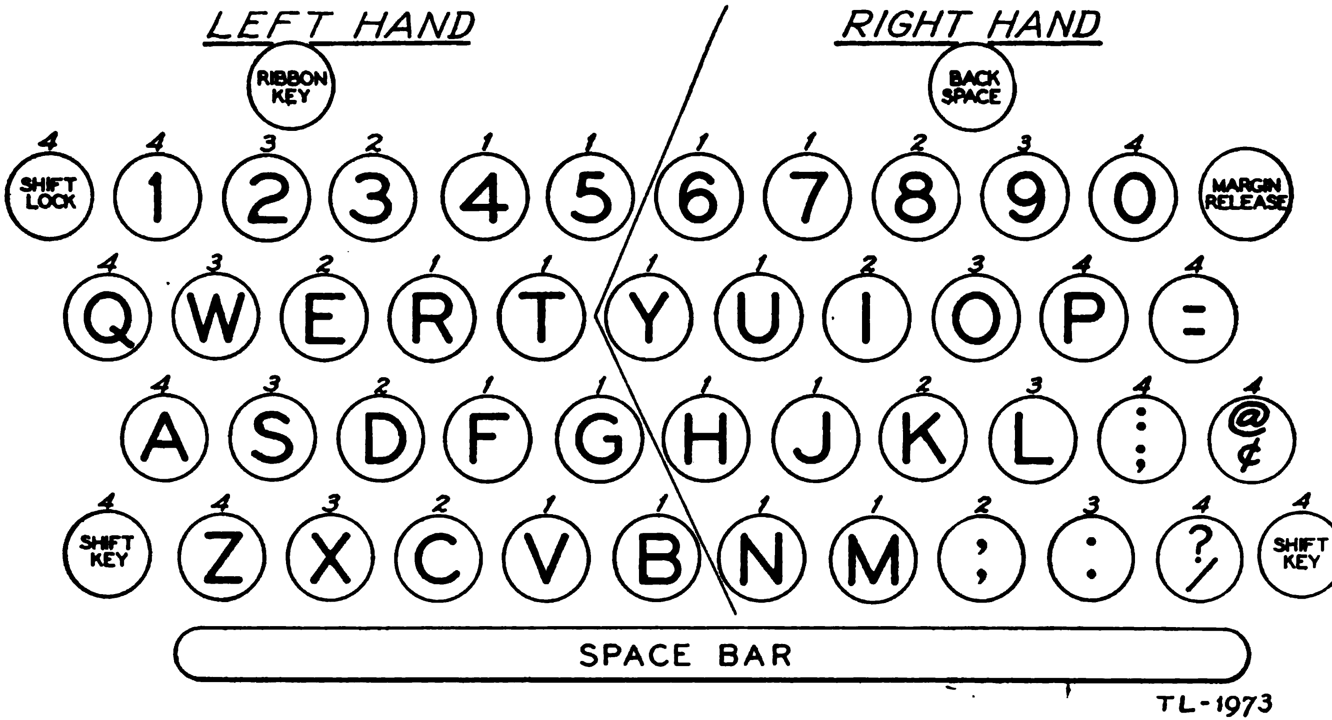

FIGURE 2.—Keyboard chart for typewriter, MC-88. (The small number above each key indicates the finger of the left or right hand to be used on that key. The typewriter, MC-88, is different from standard business typewriters in two respects: all the characters of the alphabet print as capitals, and there is a separate key for the number "1". If a standard machine is used for code transcription, the student must merely learn to use the small letter "l" to indicate the number "1"; otherwise the finger positions are the same.)

f. After having qualified at ten groups per minute, develop the habit of lettering one or two characters behind the sender. This will allow your lettering to become smooth and easy. It will also prevent you from forming the habit of trying to guess a word and of recording it before it has been completely transmitted.

14. Receiving lesson No. 1.—*a. Objective.*—To teach the sounds of the characters F, G, H, M, J, R, and U and the correct methods of recording them.

b. Information.—The characters consist of dots (short sounds—dit) and dashes (long sounds—dah). The dashes are three times as long as the dots. The sounds making up a single character are separated by a very short but uniform space of no sound. The characters included in this lesson, together with the dots and dashes and the sound of each, are shown as follows:

Character	Dots and dashes	Sound
F	· · — ·	Dit dit dah dit
G	— — ·	Dah dah dit
H	· · · ·	Dit dit dit dit
M	— —	Dah dah
J	· — — —	Dit dah dah dah
R	· — ·	Dit dah dit
U	· · —	Dit dit dah

c. Directions.—(1) Listen to the sounds and record the characters which you recognize.

(2) If recording by typewriter, use only the first finger of the proper hand for each character as shown on the keyboard chart.

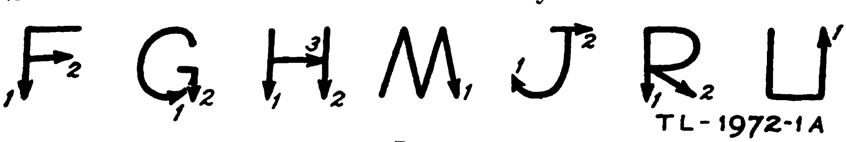

FIGURE 3.

(3) If recording by lettering, letter each character as shown in figure 3, making the strokes in the directions shown and in the order in which they are numbered.

(4) When you have recorded 100 consecutive characters that you think are correct, request the instructor to check your paper. If 50 consecutive characters are all correct and the recording has been done satisfactorily, you will be advanced to lesson No. 2.

15. Receiving lesson No. 2.—*a. Objective.*—To teach the sounds of the characters B, D, K, N, T, V, and Y and the correct methods of recording them.

b. Information.

Character	Dots and dashes	Sound
B	— . . .	Dah dit dit dit
D	— . .	Dah dit dit
K	— . —	Dah dit dah
N	— .	Dah dit
T	—	Dah
V	. . . —	Dit dit dit dah
Y	— . — —	Dah dit dah dah

c. Directions.—(1) Listen to the sounds and record the characters which you recognize.

(2) If recording by typewriter, use only the first and second fingers of the proper hand for each character as shown on the keyboard chart.

FIGURE 4.

(3) If recording by lettering, letter each character as shown in figure 4, making the strokes in the directions shown and in the order in which they are numbered.

(4) When you have recorded 100 consecutive characters that you think are correct, request the instructor to check your paper. If 50 consecutive characters are all correct and the recording has been done satisfactorily, you will be advanced to lesson No. 3.

16. Receiving lesson No. 3.—*a. Objective.*—To teach the sounds of the characters C, E, I, L, O, S, and W and the correct methods of recording them.

b. Information.

Character	Dots and dashes	Sound
C	— . — .	Dah dit dah dit
E	.	Dit
I	. .	Dit dit
L	. — . .	Dit dah dit dit
O	— — —	Dah dah dah
S	. . .	Dit dit dit
W	. — —	Dit dah dah

c. Directions.—(1) Listen to the sounds and record the characters you recognize.

(2) If recording by typewriter, use only the second and third fingers of the proper hand for each character as shown on the keyboard chart.

(3) If recording by lettering, letter each character as shown in figure 5, making the strokes in the directions shown and in the order in which they are numbered.

(4) When you have recorded 100 consecutive characters that you think are correct, request the instructor to check your paper. If 50 consecutive characters are all correct and the recording has been done satisfactorily, you will be advanced to lesson No. 4.

FIGURE 5.

17. Receiving lesson No. 4.—*a. Objective.*—To teach the sounds of the characters A, P, Q, X, Z, 4, and 5 and the correct methods of recording them.

b. Information.

Character	Dots and dashes	Sound
A	· —	Dit dah
P	· — — ·	Dit dah dah dit
Q	— — · —	Dah dah dit dah
X	— · · —	Dah dit dit dah
Z	— — · ·	Dah dah dit dit
4	· · · · —	Dit dit dit dit dah
5	· · · · ·	Dit dit dit dit dit

FIGURE 6.

c. Directions.—(1) Listen to the sounds and record the characters you recognize.

(2) If recording by typewriter use only the first, third, and fourth fingers of the proper hand for each character as shown on the keyboard chart.

(3) If recording by lettering, letter each character as shown in figure 6, making the strokes in the directions shown and in the order in which they are numbered.

(4) When you have recorded 100 consecutive characters that you think are correct, request the instructor to check your paper. If 50 consecutive characters are all correct and the recording has been done satisfactorily, you will be advanced to lesson No. 5.

18. Receiving lesson No. 5.—*a. Objective.*—To teach the sound of the characters 1, 2, 3, 6, 7, 8, 9, and Ø and the correct methods of recording them.

b. Information.

Character	Dots and dashes	Sound
1	· — — — —	Dit dah dah dah dah
2	· · — — —	Dit dit dah dah dah
3	· · · — —	Dit dit dit dah dah
6	— · · · ·	Dah dit dit dit dit
7	— — · · ·	Dah dah dit dit dit
8	— — — · ·	Dah dah dah dit dit
9	— — — — ·	Dah dah dah dah dit
Ø	— — — — —	Dah dah dah dah dah

c. Directions.—(1) Listen to the sounds and record the characters you recognize.

(2) All fingers are used in typing these characters. Use the proper finger of the proper hand for each character shown on the keyboard chart.

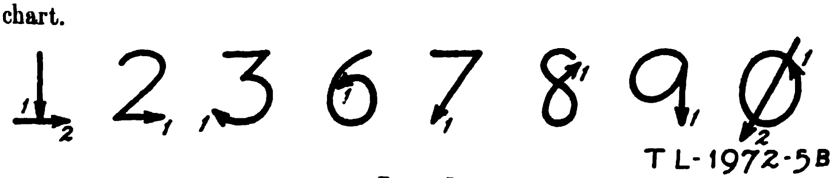

FIGURE 7.

(3) If recording by lettering, letter each character as shown in figure 7, making the strokes in the direction shown and in the order in which they are numbered.

(4) When you have recorded 100 consecutive characters that you think are correct, request the instructor to check your paper. If 50 consecutive characters are all correct and the recording has been done satisfactorily, you will be advanced to receiving practice on all characters transmitted in random order at five groups per minute.

19. Transmitting.—*a. General.*—The ability of a radio operator to transmit well-formed code characters is just as important as is his ability to recognize and record them accurately. In furtherance of this end it is essential that a student's practice transmissions be accomplished in the correct manner; habits formed when beginning to learn to send will remain with operators throughout their careers. Continuous accurate transmission of characters requires a properly adjusted key, a proper position of the operator at the key, and key operation in accordance with the principles enunciated below. When a student has demonstrated his familiarity with these principles, he begins his first transmitting exercise.

b. Key adjustment.—Figure 8 shows an ordinary closed circuit key. To adjust the key—

(1) See that the hammer is directly over the anvil. If not, loosen the lock nuts on the trunnion screws and turn these screws until the

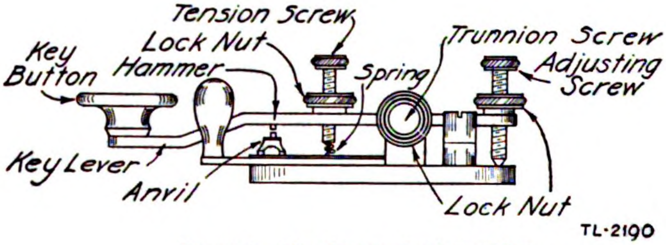

FIGURE 8.—Side view of a closed circuit key.

hammer is in the proper position and the key lever works freely without undue play. Tighten the lock nuts.

(2) Loosen the lock nut on the adjusting screw and turn this screw until the distance between the hammer and the anvil is about 0.008 inch (about the thickness of three sheets of bond paper) with the front of the key lever raised. Tighten the lock nut.

(3) Loosen the lock nut on the tension screw and turn this screw until the key can be closed easily by the hand and will be broken sharply by the spring. Tighten the lock nut.

(4) If difficulty is experienced in forming dots or dashes after the tension screw has been adjusted as in (3) above, change this adjustment until you are able to send both easily. Too much tension is usually identified with short dashes, irregular and long spacing between characters, and dot skipping. Too little tension is usually identified with long dots and short and irregular spacing between characters.

c. Position at key.—The proper position of an operator at a key is illustrated in figure 9.

(1) To assume a correct position at the key—

(*a*) Place the elbow on the table in prolongation of the key lever and at such distance from the key button that, with fingers slightly curved and the wrist about 1½ inches above the table, the ends of the first and second fingers rest easily on the distant half of the key button.

(*b*) Rest the ends of the first and second fingers lightly but firmly on top of the key button, the first joint of each finger being more nearly vertical than horizontal.

(*c*) Place the thumb lightly on the edge of the key button.

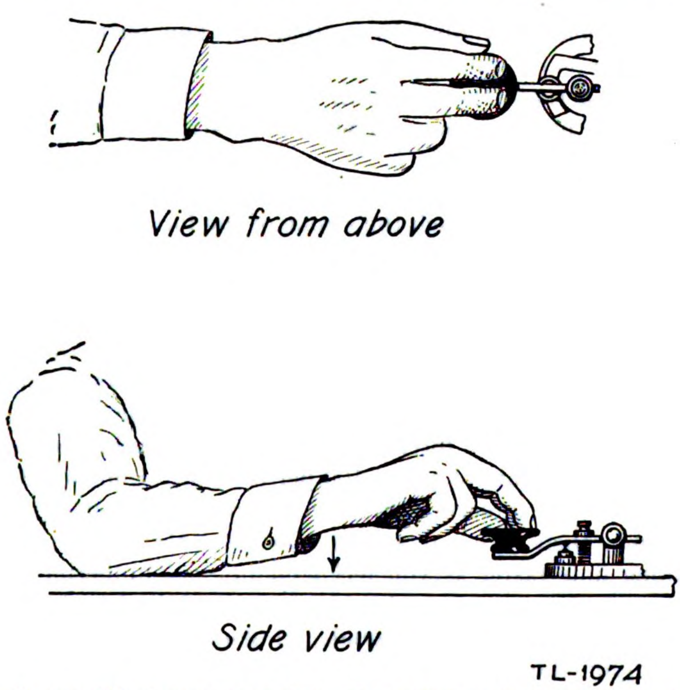

FIGURE 9.—Proper position of an operator at a key. (Note particularly that the wrist is clear of the table.)

(*d*) Allow the third and fourth fingers to curve naturally under the palm without tension or rigidity.

(2) After the sending arm, wrist, and fingers have been placed as indicated above, check their positions. See that—

(*a*) The elbow, *not the forearm*, rests on the table.

(*b*) There is space between the table and the forearm and wrist.

(*c*) The fingers are curved and flexible, not straight or stiff.

(*d*) The finger ends (pads) of the first and second fingers rest on top of the key button near the back edge.

(*e*) The thumb is on the edge of the key button, resting lightly against it, but not grasping it.

d. Key operation.—(1) *Method.*—Having assumed the proper position at the key, press down the key button by a straight downward motion of the forearm. In doing this, let the wrist break or bend downward a little, acting as a hinge between the forearm and the hand. Keep the fingers loose so that they can bend a little; in any event, do not let them be stiff. When the key contacts have been closed, release the pressure on the key button and allow the spring to return the key to the up position, keeping the fingers in light contact with the key button.

(2) *Precautions.*—(*a*) Make sure that the key button goes down because your forearm is moved down.

(*b*) Do not actuate the key with the finger muscles. The fingers are merely the medium through which the stroke of the forearm is transmitted to the key.

(*c*) Do not actuate the key with the wrist muscles. The wrist is merely a hinge through which the stroke of the forearm is transmitted to the key.

(*d*) Avoid all stiffness and rigidity in the fingers and wrist. Any such stiffness not only makes for ragged transmission but is very conducive to fatigue.

20. Transmitting exercise No. 1.—Check the key, making adjustments if necessary. Take the correct position for sending, checking the position of your forearm, wrist, fingers, and thumb. Start making dots at the rate of about 100 per minute. Continue to transmit dots until your forearm, wrist, or fingers become tired. Rest for a short time, then transmit again. *Do not make anything but dots.* Try making dots faster as you feel your muscles limbering up. Do not permit your practice to become erratic. *Send smoothly.* Try constantly to make the dots equal. If you are trying to transmit faster than you should, your sending will be rough (unequal and not rhythmic) and may "stutter." Continue your transmission of dots until you can send 30 dots in one group smoothly in about ten seconds. When you feel that you have acquired this ability, ask the instructor to check your transmission. If it is satisfactory, you will be advanced to transmitting exercise 2.

21. Transmitting exercise No. 2.—Transmit a few groups of 30 dots each, checking the position of your forearm, wrist, fingers, and thumb. Transmit the character V (dit dit dit dah), making the dits at the same rate at which you made them upon completion of exercise 1 and holding the key down for the dah 3 times as long as the time

required to transmit a dit. Allow the same space between the third dit and the dah as exists between the dits. Begin making the character V at the rate of about 35 per minute. Keep your fingers and wrist flexible. If you feel them tightening up, remove your hand from the key and flex the fingers and wrist until the muscles are completely relaxed. Continue transmitting V's until you can send 20 consecutive characters smoothly. When you feel that you have acquired this ability, ask the instructor to check your transmissions. If it is satisfactory, you will be advanced to practice transmission of the material included in appendix II.

SECTION IV

TRAINING IN RADIO OPERATING PROCEDURE

22. General.—The purpose of the radio operating procedure employed by the Army is to promote accuracy and speed in the exchange of radio messages. Radio operators trained at widely scattered stations may ultimately find themselves obliged to communicate with one another and under conditions of stress. With this in mind, it is evident that the necessity for a single precise and completely uniform system of handling radio traffic cannot be too strongly emphasized.

23. Phases of training.—*a*. The training of a radio operator in procedure may be divided into four phases:

(1) The basic training phase using code room equipment and devoted to a study of the fundamentals of procedure.

(2) A survey phase using code room equipment and devoted exclusively to the handling of traffic, simulating actual field operation as closely as possible without the use of field radio transmitters and receivers.

(3) An introductory field phase using field equipment at reduced distances.

(4) An actual field phase using regular field equipment at normal distances.

b. Phases (3) and (4) above may appear to be properly a part of technical radio operation instruction. However, there is a definite and important aspect of radio operating procedure, entirely aside from

any technical problems of the radio equipment, which can only be mastered under genuine field conditions. The radio operating procedure lessons covered herein deal only with the phases (1) and (2) enumerated above.

c. Study and practice in radio operating procedure may begin after the student has attained a code speed of five words a minute The time required to attain proficiency in field radio operating procedure depends largely upon the individual student, but a satisfactory knowledge of procedure is usually obtained in 25 to 75 hours of operation and study.

d. The comments given in paragraph 10 on duration, frequency, and relaxation for operating study apply equally well to procedure studies.

24. Flexibility of training program.—It is not essential that the instructor adhere rigidly to the training program described herein. In fact, the instructor is encouraged to inject his own personality into his teaching and to alter the style of the course freely to suit his own purpose and the needs of his class. However, the system suggested below has been found highly successful in the training of radio operators, and the program, in the main, should serve as a useful guide.

25. Instructional material.—*a. Text material.*—If this manual is not available for each member of the class, the instructor should provide mimeographed copies of the first lesson to the entire class at the beginning of the course and copies of additional lessons to students as their progress warrants it. Further, a list of procedure signals and procedure signs as found in the appendixes should be made available to each student. In all units using the abbreviated form of message exclusively, sections V to IX, inclusive, XI, and XII provide adequate training material for the essential principles.

b Station logs—During the initial training phase, logs should be employed which provide for the recording of all signals heard and transmitted. A suitable training log is shown in FM 24-5. During the second phase of training, when operators are able to carry on with a minimum of supervision, the practical type of log is the regular field log. This type of log is shown in figure 10.

c. Prepared messages.—Beginning with radiotelegraph procedure lesson IV, it is necessary for the instructor to prepare "canned" messages for transmission. The messages listed in appendix II may serve for this purpose, or these specimen messages may be used as guides to assist the instructor in preparing additional messages.

d. Message book.—The standard field message form is used for both transmitted and received messages.

SIGNAL CORPS, UNITED STATES ARMY

LOG

Enter opening and closing time, frequencies and frequency changes, traffic delays and any incidents or conditions affecting circuit efficiency

STATION LC 13TH INF DATE 4 MARCH

TIME	OPERATOR	REMARKS
922A	A-X	CENTERVILLE 41ØØ KC REPORT IN TO LA (NCS) OUR SIGS ZSB4 AT LA
929		LB IN NET OUR SIGS ZSB3 AT LB
945		LA DOES NOT ANSWER CALL-UP
1ØØ3	X-A	X TO KEY A TO GENERATOR
1ØØ7		LA REPORTS BY WIRE CKT HE IS TEMPORARILY SILENCED BY ORDER CG
1212P	W-A	W RELIEVES X
1235	W-T	T RELIEVES A
211		BLUE GLOW IN AMPLIFIER TUBE DRAWING EXCESSIVE CURRENT
214		REPLACE AMP TUBE PLATE CURRENT OK
45Ø	A-X	RELIEVE W-T
632		CLOSE STATION FOR MOVE
84Ø		BLUFTON 41ØØ KC REPORT IN TO LA OUR SIGS ZSB5 AT LA ZSB4 AT LB
91Ø		NET SHIFTS TO 412Ø KC ON ORDER OF LA
1Ø26		MICROPHONE ACCIDENTALLY DROPPED LA REPORTS PHONE QUALITY POOR NO SPARE MIKE ON HAND
1119		CLOSE STATION FOR MOVE

TL-2186A

FIGURE 10.—Sample station log with typical entries.

26. Conducting the class.—*a*. The order of administering an instructional period is as follows:

(1) The instructor distributes the necessary text material and delivers any introductory remarks which he feels advisable for supplementing the text.

(2) The students study the text.

(3) The students ask questions of the instructor on any point which they do not understand.

(4) The instructor gives a written quiz on the subject matter of the lesson.

(5) The students practice transmitting individually, during which time the instructor grades the quizzes.

(6) Those students who pass the quiz are grouped into nets of three stations each to carry out the operations prescribed in the operation exercise for the corresponding lesson. Any student who fails initially to pass the quiz must review the lesson at his desk. He is then given a second opportunity to take the same quiz whenever he feels adequately prepared. This process is continued, if necessary, until each student successfully completes the quiz and proceeds to the operation exercise.

(7) Students completing an operation exercise submit their log sheets and copies of all messages handled, both transmitted and received, to the instructor for check, and then study the next lesson.

(8) A written quiz on the information contained in the next lesson is given to any student who feels adequately prepared and whose log sheet on the previous lesson is found to be satisfactory.

(9) At the close of an instructional period, nets which have not completed their operation exercises simply stop at any convenient point and resume operation at that point at the opening of the following instructional period without any apparent break being shown on the log sheets. Operators always retain their log sheets until all operations described in that lesson are completed.

b. The method of teaching indicated in *a* above has the advantage of automatically dividing the class into groups, so that the instructor may concentrate his attention on the slower students, who need the most assistance; and of providing an incentive to the better students to work as fast as they desire, and so reducing the training time to a minimum. One or more assistant instructors are desirable if the class is large, although it is possible for one instructor with some experience to handle successfully a class of as many as 50 men.

c. In this series of lessons all references to recording received material imply lettering with pencil. The instructor checking

received messages should emphasize good lettering as much as accurate copying, since the radio operator's copy must normally be legible to other personnel for deciphering. Typewritten copy is permissible. However, typewriters are rarely available to field radio stations, and training should be handled accordingly.

d. An effective arrangement of the three key operators in any one net is one fast operator and two slower operators rather than three fast operators in any one net and three slow operators in another. A man who shows good aptitude for transmitting and receiving ordinarily also exhibits ready understanding of procedure. Such a man generally sets an example of good operating procedure, and, if desired, he may incidentally be employed as an assistant instructor to guide the operators at the other two stations of the net. It is not intended that the net control station (NCS) assignment should be confined to the best operator; this assignment should be rotated to provided equal opportunity for all students to practice NCS responsibility.

27. Measurement of progress.—*a. General.*—The objective of net training is to provide operators with a thorough understanding of operating procedure. Emphasis is placed on thorough training rather than on putting all men through the course in the same length of time. If any individual student is unreasonably slow, it is best to arrange for his release from training and to recommend his transfer to other duty. All grading of individual items in the course should be either "pass" or "fail." A student must repeat each item as many times as necessary to insure mastery before proceeding to the succeeding material.

b. Grading quizzes.—Quizzes are retained by the instructor. The instructor summons each student to his desk individually, or the instructor may visit each student at the latter's desk, and grades each particular quiz in the writer's presence. In this way the student sees his paper checked and has an opportunity for personal discussion of any item with the instructor. Quizzes are graded either "pass" or "fail" according to the judgment of the instructor on how well the student has grasped the essential points involved.

c. Grading logs.—Log sheets may be partially checked by the instructor, using a colored pencil, as he observes the various nets in actual operation. This system of checking logs, over the students' shoulders, promotes further close contact between student and instructor and facilitates both teaching and grading. Occasionally, if errors of important basic points of operation are indicated by the logs of any one net, it may be well for the instructor to stop that

particular net, point out the errors, and have all stations in the net repeat the complete operation. Logs are graded "pass" or "fail" depending upon whether or not the indicated performance of the operations is satisfactory.

d. Progress chart.—The instructor will find it advantageous to employ a wall or blackboard chart such as shown in figure 11 for keeping a record of the progress of each member of the class.

Name	Lesson number											
	1	2	3	4	5	6	7	8	9	10	11	....
Allen	×	×	×	×	×	×						
Brown	×	×	×	╲								
Doe	×	×										
Johnson	×	×	×	×	╱							

Key

╲ completed quiz
╱ completed operation
× completed lesson

FIGURE 11.—Progress chart.

SECTION V

RADIOTELEGRAPH PROCEDURE LESSON I, THE CALL-UP AND ANSWER

28. Call signs.—All radio stations are identified by call signs, for example, WLW is the call sign of a broadcasting station in Cincinnati; WAR is the call sign of the War Department station in Washington, D. C. Call signs for the various Army stations in the field are nor-

mally assigned in Signal Operation Instructions (S. O. I.). An example of a list of call signs is given in FM 24-5. The S. O. I. in effect may prescribe that call signs change at a time when stations are in operation. This change is made automatically by each station at the specified time with no attendant formalities and with no interruption of radio communication.

29. The call-up.—*a. Definition.*—A station whose call sign is LB contacts a station whose call sign is LA by means of the "call-up":

LA V LB $\overline{\text{AR}}$

In the above, V is an abbreviation for "from", and $\overline{\text{AR}}$ means "end of transmission and standing by to receive your reply".

b. Repetition of call signs in a call-up.—Each station's call sign may be transmitted more than once in a call-up but not more than three times. Example:

LA LA LA V LB LB LB $\overline{\text{AR}}$

In establishing contact between two stations, the transmitting operator may call three times and sign three times, as in the above example, in order to give the receiving operator the utmost opportunity to tune in the signal. Repeated calls are also permissible at any time under doubtful or definitely adverse communication conditions, such as during heavy static. However, the student must constantly bear in mind the possibility that in actual field operations enemy position-finding stations will welcome a radio operator's prolonged transmissions. One goal of training should be station contact and message exchange with the fewest and shortest possible transmissions. Recommended procedure in this connection is illustrated in *c* below.

c. Repetition of call-up.—In an initial call-up call signs are transmitted only once. If a called station fails to answer an initial call-up promptly, the call-up may be repeated immediately, with the call signs therein sent three times. If the second call-up is not answered, the calling station should wait at least two minutes before transmitting a third call-up. Any additional call-ups necessary before receiving an answer should be at intervals of at least five minutes, except when the calling station has an urgent or priority message for the called station, in which case no restriction is placed upon such repetitions.

Original call-up	LA	V	LB	$\overline{\text{AR}}$				
Second call-up	LA	LA	LA	V	LB	LB	LB	$\overline{\text{AR}}$
2 minute (or greater) interval								
Third call-up	LA	LA	LA	V	LB	LB	LB	$\overline{\text{AR}}$
5 minute (or greater) interval								
Fourth call-up	LA	LA	LA	V	LB	LB	LB	$\overline{\text{AR}}$

30. Collective call-up.—In the event that a station wishes to gain the attention of two or more stations simultaneously, a prearranged "collective" call sign may be used. Thus, the call sign ABC may be designated to include three stations, LA, LB, and LC. One of the stations, LC, should call LA and LB simultaneously by transmitting the collective call-up:

A B C V L C $\overline{\text{AR}}$

31. Multiple call-up.—In the absence of a prearranged collective call sign which includes all the stations with which communication is desired, these stations may be called simultaneously by simply transmitting the call signs of each desired station in sequence. This is known as a "multiple" call-up. Example:

L A L B X A V L C $\overline{\text{AR}}$

The prescribed order of call signs is alphabetical if their first symbol is a letter as in the above illustration. The call signs are arranged in ascending numerical order if their first symbol is a number as shown below.

2C 3A 4B V L C $\overline{\text{AR}}$

32. The answer.—*a Definition.*—Station LA, upon hearing a call-up from LB, would answer by transmitting:

L B V L A K

K means "go ahead (transmit)".

b. Order of answering.—(1) The order of stations answering a multiple call-up is the same as the order in which their calls appeared in the original call-up.

Call-up	**L A**	**L B**	**X A**	**V**	**L C**	**$\overline{\text{AR}}$**
First station to answer	**L C**	**V**	**L A**	**K**		
Second station to answer	**L C**	**V**	**L B**	**K**		
Third station to answer	**L C**	**V**	**X A**	**K**		

(2) In answering a collective call-up, the called stations answer in alphabetical or numerical order of call signs. If call signs beginning with both numerals and letters are used in the same net, the stations having call signs beginning with letters will answer first, alphabetically; they will be followed by the stations having call signs beginning with numerals, answering in numerical order. Again taking the collective call sign ABC to include LA, LB, and LC:

Call-up	**A B C**	**V**	**L C**	**$\overline{\text{AR}}$**
First station to answer	**L C**	**V**	**L A**	**K**
Second station to answer	**L C**	**V**	**L B**	**K**

(3) If a called station fails to answer a multiple or collective call-up in its turn, the next station in order, after waiting 15 seconds, answers; and the delinquent station does not answer until all other stations have answered.

Call-up	LA	LB	XA	V	LC	$\overline{\text{AR}}$
First station to answer	LC	V	LA	K		
15-second interval						
Second station to answer	LC	V	XA	K		
Third station to answer	LC	V	LB	K		

c. Answering a station whose call sign is unknown.—Occasionally a receiving station recognizes its own call in a call-up but fails to distinguish the call sign of the calling station. Such a call-up would be answered by the use of the "unknown station" procedure sign $\overline{\text{AA}}$. Thus FG, having heard someone call him but not being certain who called, transmits:

$\overline{\text{AA}}$ V FG K

The calling station then repeats its call-up:

FG V XY $\overline{\text{AR}}$

33. Procedure signs.—The abbreviations V, $\overline{\text{AR}}$, and K, which appeared in the above call-ups and answers, are three of a group of commonly used radio abbreviations referred to as "procedure signs." The complete list of procedure signs is given in appendix III. A partial list is given below:

Procedure sign	*Meaning*
$\overline{\text{AR}}$	End of transmission.
EEEEEEEE	Error. Erase.
$\overline{\text{IMI}}$	Repeat. Question mark.
K	Go ahead. (Transmit.)
V	From. Calling.
$\overline{\text{VA}}$	Finish.

34. Procedure signals.—*a. Definition.*—Another type of abbreviation used in Army radio communication is the "procedure signal." A procedure signal is a three letter group, often called a "Z" signal because its first letter is Z, representing some frequently used complete expression which facilitates conversations between operators. The second letter of a procedure signal characterizes the signal as of a particular classification, and the third letter distinguishes any one procedure signal from others of the same classification. With some procedure signals, as will be seen in the partial list below, blanks are indicated in the meanings given. All blanks except those in

parentheses are required to be filled in by the transmitting station. Those in parentheses are filled in if desired. In all cases filled-in data follow the procedure signal and appear in the same order as the blanks filled in. Except as otherwise noted, words rather than numerals are used to complete the meanings of procedure signals. Thus, to express "I am in radio communication with LA", a station transmits: ZCB LA ONE and not ZCB LA 1.

b. Examples.—A partial list of procedure signals is given below. A complete list of procedure signals will be found in appendix III.

Classification	Procedure signal	Meaning
C: Calling; communication.	Z C A	Are you (or is ------) in communication with ------ (by ------) (1. Radio; 2. Wire; 3. Visual)?
	Z C B	I am (or ------ is) in communication with ------ (by ------) (1. Radio; 2. Wire; 3. Visual).
M: Messages --------	Z M A	I have (or ------ has) (------) messages (numeral indicating number of messages may be followed by O, P, or D to indicate precedence other than routine) for you (or ------).
	Z M W	Of what precedence and to whom are your messages?
Z: Miscellaneous -----	Z Z B	Negative, no, not.
	Z Z C	Affirmative, yes.

c. Use.—(1) As an illustration of the use of procedure signals, consider ZMW, meaning: "Of what precedence and to whom are your messages?" (Messages are given precedence according to their relative importance and urgency as designated by the originator.) Station LB might ask station LA:

LA V LB ZMW $\overline{\text{AR}}$

to which, in the event that station LA has no messages whatsoever on hand to transmit, LA would reply:

LB V LA ZMA ZERO $\overline{\text{AR}}$

ZERO is used in the above rather than NONE to avoid the possibility of the receiving operator's mistaking NONE for ONE.

(2) Procedure signals are the only authorized means other than regular messages for conversations between operators. If procedure signals are found to be inadequate, the chief operator or chief of a

station may authorize the transmission of messages relating to the conduct of communications.

35. Terminating transmissions.—Some sort of terminating sign is necessary to indicate when the transmitting station cedes the air to the receiving station. The following examples illustrate the uses of various procedure signs which are employed for the purpose.

a. $\overline{AR}$: "*End of transmission.*"—This has the meaning, "I am through with this transmission, you may respond if a response is in order or necessary." Example:

LA V LB ZMW $\overline{AR}$

LB expects a reply to his query and so terminates his transmission with $\overline{AR}$. For an additional example:

LA V LB $\overline{AR}$

Station LB has called up station LA with the intention of sending LA something and now anticipates a "go ahead" sign from LA before proceeding. Without the $\overline{AR}$ on the end, LA is not sure whether LB has just paused briefly in his transmitting or is definitely standing by waiting for LA to reply. The use of the $\overline{AR}$ removes this uncertainty.

b. K: "*Go ahead, transmit.*"—One station LA, having been informed that another station, LB, has something to transmit to LA advises LB to proceed by means of the terminating sign K, which means "Go ahead, transmit." LB might have advised LA of his desire to transmit something to LA by stating:

LA V LB ZMA ONE $\overline{AR}$

LA prepares his message form in anticipation of receiving a message from LB and transmits:

LB V LA K

that is, LA says to LB, in effect: "Go ahead, transmit. I am ready to copy."

When a receipt is required, a transmission will end with K. This applies mainly to regular messages, but it may also apply to any special instructions in the form of procedure signs or signals for which the transmitting station wants receipts as a matter of record or information. For example, station CB desires station RU's last message verified and repeated, and also desires a receipt for this request itself:

RU V CB J K

RU receipts simply:

CB V RU R

As soon as the message is verified, RU calls CB back and repeats the

message as requested. Examples of the use of K with messages will be found in sections VIII, IX, and X. When a receipt is not required, a transmission will end with $\overline{\text{AR}}$ or some other appropriate terminating sign.

c. $\overline{VA}$: "*Finish*".—$\overline{\text{VA}}$ is employed—

(1) To terminate a transmission to which an acknowledgment or reply is prohibited or not expected, or:

(2) To indicate to the receiving station that henceforth until some future time, the transmitting station will no longer be in communication with the receiving station, as, for instance, should the transmitting station be closing down to displace to a new position, or closing down until the next regular operating schedule, or leaving the net (by shifting frequency) to operate with a station in another net.

d. Other procedure signs which may be employed for terminating transmissions are B, which means "More to follow"; C, "Affirmative. Correct"; $\overline{\text{IMI}}$, "Question mark"; N, "Not received. Negative"; R, "Receipt"; J, "Verify and repeat"; Y, "Acknowledge." Various examples of the uses of these procedure signs occur in the text of this manual.

36. Correction of error.—When an error is made in transmission, the transmitting operator immediately makes the "error" sign (EEEEEEEE), then repeats the last word, group, or procedure sign or signal which was correctly made and continues with the transmission. Example:

LA U EEEEEEEE LA V LB $\overline{\text{AR}}$

37. Repetitions.—*a. Repetition of transmission.*—A request for a repetition of a complete transmission is made by sending $\overline{\text{IMI}}$. Thus:

LA V LB $\overline{\text{IMI}}$ $\overline{\text{AR}}$

In response to the above request station LA would repeat its entire previous transmission.

In this case $\overline{\text{IMI}}$ is a little message meaning "Please repeat the last transmission", and it therefore requires a separate terminating sign. $\overline{\text{IMI}}$ is a terminating sign by itself when it is used as a question mark after some other procedure sign or signal, to give it an interrogatory meaning, as in paragraph 46*c* and *f*.

b. Repetition of difficult portion.—$\overline{\text{IMI}}$ may also be used to indicate that the transmitting operator is about to repeat a difficult portion to insure the correct reception by the receiving operator. Example:

LA V LB $\overline{\text{BT}}$ BODY OF VISCAY
A ZULANGA $\overline{\text{IMI}}$ VISCAY A ZULANGA FOUND
1052P K

38. Questions for self-review.—The student should answer each of the following questions as a test of his understanding of the lesson.

a. How does one station contact another?

b. How many times may each station's call sign be transmitted in a call-up?

c. What action would you take if a station failed to answer your initial call-up?

d. What is a collective call-up?

e. What is a multiple call-up?

f. In what order is a multiple call-up answered?

g. If a called station failed to answer a collective call-up in its proper turn how long should the next called station in order wait before answering?

h. The meaning of the procedure signal ZMA is given as: "I have (or ——— has) ——— messages (numeral indicating the number of messages may be followed by O, P, or D to indicate precedence other than routine) for you (or ———)." Of the blanks provided in the stated meaning of ZMA, the first and third are inclosed in parentheses whereas the second is not. What is the significance of this usage of parentheses?

i. How would you request a repetition of a complete transmission which you had missed?

j. In a message made up of code groups, which you are about to transmit, one group is SEIS, conceivably difficult to receive on account of the succession of dots involved. How might you make your transmission to assist the receiving operator on this difficult group?

k. Correct the following transmissions:

(1) **LA LA LA V LB LD $\overline{\text{IMI}}$ LB LB LB $\overline{\text{AR}}$**
(2) **LA LA LA V LB LD EEEEE LB LB LB AR**
(3) **LA LB FG V LC $\overline{\text{AR}}$**
(4) **NOW IS THE TIMI EEEEEEEE TIME FOR ALL GOOD MEN**
(5) **ZCA LB 3 LA**
(6) **ZCB ZZB LA LC**

39. Sample quiz.—The following is a suggestion for a quiz covering the principles enunciated in lesson I. Sample quizzes are not illustrated in this manual for any of the succeeding lessons, the writings of these quizzes being left to the instructor. The instructor is cautioned to examine quiz questions carefully to avoid ambiguities. Having an assistant take the quiz before it is submitted to the students will often serve to bring out any unsuspected defects in the quiz.

Quiz on operation lesson I

Directions to the student: Fill in all spaces. Print plainly. Assume that you are the operator at station LA.

1. You wish to ask LB of what precedence and to whom are his messages. Show your transmission to LB.

---

2. You intend to transmit the following.

LB V LA $\overline{\text{AR}}$

However, you accidentally make LR instead of LA in the actual transmission. Show your complete transmission to LB including the error and its correction.

---

3. Assume that CD did not receive your transmission of question 2. Show how he would request a repetition.

---

4. Using a multiple call-up, indicate how you would request LB, LE, LD, and LC to inform you if they are in communication with BZ by wire.

---

5. Show the replies of the individual stations in the proper order to your request of question 4. Assume that LE and LB are not in wire communication with BZ but that LD is; LC has just developed transmitter trouble and is unable to reply by radio. Indicate the occurrence and the duration of any extended pauses.

---

40. Operation exercise.—*a. Directions to the student.*—The net consists of three stations, LA, LB, and LC. The collective call sign which includes all three stations of the net is ABC. For simplicity any repeated group may be recorded once with a superscript to indicate the number of times the group was actually transmitted. Thus

LA LA LA V LB LB LB $\overline{\text{AR}}$

may be recorded as

LA^3 V LB^3 $\overline{\text{AR}}$

Execute the following communications in the order listed, recording every transmission (including your own) directly on the log sheet.

b. Exercises.—(1) Station LA will call up station LB and ask if LB has any messages for LA.

(2) Station LB will answer station LA, and state that he has no messages for LA.

(3) Station LA will call up station LC and ask if LC has any messages for LA.

(4) Station LC will answer station LA and state that he has no messages for LA.

(5) Station LA will call up stations LB and LC using a multiple call-up and ask if they are in wire communication with station BA.

(6) Stations LB and LC will answer in the proper order, LB answering in the affirmative, LC in the negative.

Request the instructor to check the log at this point before continuing

(7) LB will call up LC and ask if LC has any messages for LB.

(8) LC will answer LB and state that he has no messages for LB.

(9) LB will call up LA and ask if LA has any messages for LB.

(10) LA will answer LB and state that he has no messages for LB.

(11) LB will call up LC and LA using the collective call sign assigned to the net and ask them if they are in radio communication with FG.

(12) LC and LA will answer in the proper order, LC answering in the affirmative, LA in the negative.

Request the instructor to check the log at this point before continuing

(13) LC will call up LA and ask if LA has any messages for LC.

(14) LA will answer LC and state that he has no messages for LC.

(15) LC will call up LB and ask if LB has any messages for LC.

(16) LB will answer LC and state that he has no messages for LC.

(17) LC will call up LA and LB using the net call and ask if LA and LB are in communication with FG.

(18) LA and LB will answer in the proper order, LA stating that he is not in communication with FG, and LB stating that he is in communication with FG by wire.

SECTION VI

RADIOTELEGRAPH PROCEDURE LESSON II, READABILITY, THE STATION LOG

41. Readability.—*a. Readability scale.*—It is of interest to a transmitting operator to know the "readability" of his signal at the receiving station. By "readability" is meant an estimate of the ease with which the receiving operator can make intelligent copy. This estimate depends partly upon the relative strength of the desired versus the undesired (interference, static, inherent receiver noise, etc.) signal and partly upon the capabilities of the receiving operator. A numerical scale of readability has been adopted as follows:

(1) Unreadable.

(2) Poor but readable; make plain language messages through twice, code unreadable.

(3) Fair; readable; plain language once slowly, make code messages through twice.

(4) Good; readable; plain language or code once.

(5) Perfectly readable.

b. Request for readability.—An operator may request a readability report by the use of the procedure signal ZSG. Thus:

LA V LB ZSG $\overline{\text{AR}}$

LB might reply:

LB V LA ZSB4 $\overline{\text{AR}}$ (Readability 4)

Since ZSG means "What is my readability?", it is not necessary for LA to fill in the first blank in the meaning of ZSB, "I can receive ——— Readability ———", as this would merely be a repetition of LB's own call. This is an exception to the rule that all blanks in Z signals not in parentheses be filled. However, note the full use of ZSB in case LB asks LA about a third station, LC.

LA V LB ZSA LC $\overline{\text{AR}}$

LA would then answer

LB V LA ZSB LC 4 $\overline{\text{AR}}$

c. Exchange of readabilities.—Operators may exchange readability reports without mutual request on first establishing communication with each other. Suppose station LA has heard station LB transmitting to station LC. LA, noting that LB's signal is perfectly readable, transmits a report of this readability on his initial call-up of station LB.

LB V LA ZSB5 $\overline{\text{AR}}$

The $\overline{\text{AR}}$ with which LA concludes his transmission indicates that he expects a readability report from LB. LB then replies:

LA V LB ZSB4 $\overline{\text{AR}}$

d. Change of readability.—In the event of any change of readability later in the day, a readability report so indicating is promptly transmitted. Thus, suppose that while LB is informing LA that he has a message for LA, an interfering station causes LB's readability at LA to drop from 4 to 3. LA might send:

LB V LA ZSB3 K

LB would comply by transmitting all coded groups twice and all plain language once slowly, continuing in this manner until advised by LA of any further change in readability.

e. Change of readability due to frequency shift.—In the event of a readability drop caused by some drift or accidental shift in a transmitter's frequency, the procedure for correcting the frequency to obtain better readability is illustrated in the following:

LA V LB ZFO $\overline{\text{AR}}$ (Your frequency is too high.)

or

LA V LB ZFO 15 $\overline{\text{AR}}$ (Your frequency is 15 kilocycles too high.)

Station LA adjusts his transmitter to restore his frequency to the proper value and then asks:

LB V LA ZFM $\overline{\text{AR}}$ (How does my frequency check?)

To which LB might reply:

LA V LB ZFN ZSB4 $\overline{\text{AR}}$ (Your frequency is correct. Readability good.)

42. Signal and interference strengths.—Strength of signals and of interference may be expressed by the use of procedure signs S and W, respectively, together with an appropriate numeral according to the following scale:

Very weak; hardly audible	1
Moderately weak	2
Medium strong	3
Moderately strong	4
Strong	5

LB might report to LA:

LA V LB ZSB4 W3 FG $\overline{\text{AR}}$

meaning "readability good; medium strong interference from station FG."

43. Test signals.—If one station has difficulty tuning in another's signals, the first station may request, by the use of the procedure

signal ZFD, that the second station send a series of V's (the standard test signal):

LA V LB ZFD $\overline{\text{AR}}$
LB V LA V V V V V $\overline{\text{AR}}$
LA V LB ZSB5 $\overline{\text{AR}}$

Or if LB wished to tune in LA on a different frequency, say 4210 kilocycles, LB might request:

LA V LB ZFD 4210 $\overline{\text{AR}}$

(Numerals, not words, are used to indicate frequencies and frequency deviations in procedure signals.)

44. The station log.—*a. Log material.*—The station log is the radio operator's diary. A reasonable rule to follow in selecting material to be entered in the log is to enter sufficient information to enable a replacement operator to carry on at any point merely by reference to the log. In case of doubt as to whether or not an item is important enough to record, it is generally well to record it. What appears to be inconsequential at one time may develop to be of genuine importance later. However, the keeping of the log must not delay the handling of traffic. The log always includes, among other things, such data as—

(1) Names of operators on duty.
(2) Times of opening and closing of station.
(3) Causes of delays in traffic.
(4) Frequency adjustments and changes.
(5) Unusual occurences, such as procedure violations.

b. Recording.—Log items are a matter of semipermanent record. Items are entered in the log immediately following the occurence of the incidents being reported, or as soon thereafter as the traffic situation permits. Entries are not erased. Any necessary changes are made by drawing a line through the original statement and indicating the changed version alongside or nearby.

c. Student log.—During the initial instruction phase and until advised to the contrary by the instructor, the student will enter the five minimum essentials listed in *a* above and will continue to record in the log every transmission in the net with the single exception that a transmitted message may be indicated in the log by a notation "Sent msg" or "Repeated msg", instead of including the entire transmitted message in the log. The original copy of the message on the message blank delivered to the operator from the (simulated) message center will be considered adequate record of a transmitted message. However, any received message, regardless of whether it

corresponds to an original transmission or to a repeat, is copied completely in the log.

d. Log for trained operator.—The amount of detail to be entered in the log may vary with the state of training of the student. As training progresses to a point where the student is able to handle traffic without close supervision, the entries in the log may be reduced to simply the five minimum essentials listed in *a* above. A typical log for an experienced operator is shown in figure 10.

e. Personal sign.—In the column marked "operator" in the log shown in figure 10, each letter designates an operator and is known as that operator's "personal sign". Each operator at a station has a distinguishing personal sign of one or two letters (not necessarily his initials) with which to identify himself in the station records. This personal sign is never transmitted.

45. Time notations.—*a.* In Army radio operations, time notations in logs and elsewhere are in the usual 12-hour system, the new day starting at midnight. Except for midnight and noon, which are spelled out MIDNIGHT and NOON respectively, time groups are always designated by numerals. 600A is used to indicate 6:00 A. M., 512P for 5:12 P. M. ZCC 733P means, "Call me again at 7:33 P. M."

b. In joint Army and Navy communications, time is expressed in the 24-hour clock system and is transmitted as a group of four figures. The first two digits represent the hours from midnight and the last two the minutes past the hour. Thus, 6:00 A. M. in the ordinary 12-hour system becomes 0600; 7:43 P. M. is 1943.

46. Procedure signs.—*a. R: "Receipt."*—R is used to mean "receipt" of a preceding transmission, particularly one ending in K. For example, LA, having just received a message from LB, transmits:

LB V LA R

As a simple acknowledgment of receipt, R may be used alone, as above. However, the terminating sign K may be necessary, as in *b* below. R may also be followed by $\overline{\text{VA}}$, when, for instance, a receiving station acknowledges receipt of instructions from the net control station to close down station. Example:

LA V LB ZWA K

LB V LA R $\overline{\textbf{VA}}$

b. B: "More to follow."—B is used to terminate a transmission when the transmitting operator wishes to indicate that there is more to follow.

LA V LB -------- (message) **B**

When B is used along this way, the receiving operator knows that he must prepare another message form, and the transmitting operator pauses for a second or two to allow the necessary time.

If station LB desires a receipt for the first message before proceeding with the next one, he should send:

LA V LB ------ (message) **B K** (more to follow; receipt for this one first)

If he received the message properly, and is ready for the next one, LA should transmit:

LB V LA R K (message received; go ahead with next one)

c. Suppose that LA has transmitted a message to LB, and during the sending LB's transmitter breaks down. On next contacting LB, LA might ask:

LB V LA R $\overline{\text{IMI}}$

meaning "Did you receive my last message?" to which, if LB had received the message, LB would reply:

LA V LB R

d. N: "Not received."—If in *c* above, LB had not received the message, LB would reply:

LA V LB N K (Not received; go ahead)

e. $\overline{AS}$: "Wait."—$\overline{\text{AS}}$ is used to mean, "Wait, and stand by for further communication." Example:

LA V LB $\overline{\text{AR}}$

LA may require a few seconds perhaps to locate a fresh message form or possibly to replace a lead in a pencil. LA sends:

LB V LA $\overline{\text{AS}}$

LB does not answer but stands by tuned in to LA awaiting further instructions by LA. The procedure sign $\overline{\text{AS}}$ is transmitted once every 30 seconds until LA is ready for LB to transmit. LA then sends:

K

and LB proceeds.

f. $\overline{IMI}$: "Repeat. Question mark."—To request repetition of doubtful or missed parts of a message, study the examples in paragraph 68.

$\overline{\text{IMI}}$ may be used to request verification of doubtful reception, without necessarily asking for repetition. For example, station LA questions his reception from LB of the word HANSE after LAROW:

LB V LA LAROW HANSE $\overline{\text{IMI}}$

If this is correct, the reply is:

LA V LB C

$\overline{\text{IMI}}$ is especially useful as a means of enabling a procedure signal to be read as a question in case the desired question is not listed; $\overline{\text{IMI}}$ is simply placed after the signal whose meaning is to be changed to the interrogative sense. Care must be taken that the signal so constructed will not be interpreted wrongly at the receiving station. Likewise, the procedure signal ZZB may be put in front of another procedure signal to give it a negative meaning. The following examples show some of the possibilities:

"I have been calling you on 2980 kc."—ZCE 2980
"Have you been calling me on 2980 kc.?"—ZCE 2980 $\overline{\text{IMI}}$
"I have not been calling you on 2980 kc."—ZZB ZCE 2980
"Make preliminary call-up before transmitting traffic."—ZCL
"Shall I make preliminary call-up before transmitting traffic?"—ZCL $\overline{\text{IMI}}$
"Do not make preliminary call-up before transmitting traffic."—ZZB ZCL

g. $\overline{\text{XE}}$: *Separator sign.*—Just as punctuation marks are used to set off portions of a sentence for clarity, so the separator sign, $\overline{\text{XE}}$, may be used to "punctuate" and clarify a transmission. The transmission illustrated in paragraph 42 might better have been:

LB V LA ZSB4 $\overline{\text{XE}}$ WS FG $\overline{\text{AR}}$

h. List of procedure signs.—Those procedure signs which are introduced in this lesson are tabulated below for convenience in reference and study.

Procedure sign:	*Meaning*
$\overline{\text{AS}}$	Wait.
B	More to follow.
$\overline{\text{IMI}}$	Repeat. Question mark.
N	Not received. Negative. Exempted.
R	Receipt. Routine.
S	Signal strength.
W	Interference.
$\overline{\text{XE}}$	Slant (/) or separator.

47. Procedure signals.—The following procedure signals with their meanings should be memorized:

Classification	Procedure signal	Meaning
C: Calling; communication.	Z C C	Call me again at ——— (on ——— kc.).
F: Frequency; frequency adjustments.	Z F D	Send V's on this frequency (or ——— kc.).
	Z F M	How does my frequency check?
	Z F N	Your frequency is correct.
	Z F O	Your frequency is too high (or is ——— kc. too high).
	Z F P	Your frequency is too low (or is ——— kc. too low).
O: Operating	Z O A	Send at speed of ——— words per minute.
	Z S B	I can receive ———. Readability ———.
S: Signals; readability	Z S F	What is my signal strength?
	Z S G	What is my readability?

48. Questions for self-review.—*a.* A received signal is quite loud. However, on account of the presence of temporary unavoidable, disturbances near the radio station, intelligent copy is impossible unless the transmitting operator sends plain language once slowly and code twice. What is the correct readability signal to describe these conditions?

b. What is the proper readability report to designate that the received signal, although discernible, is not good anough to permit copying plain language even if each group is sent twice?

c. In adjusting your transmitter for optimum output, which would you request of the receiving operator, ZSG or ZSF? Why?

d. In the ordinary exchange of traffic, which is of the most importance, readability or signal strength? Why?

e. How would you inform another station that its frequency is ten kilocycles too low?

f. Name the five items required to be entered in every station log.

g. Criticize the following transmissions:

(1) Z C C N I N E A
(2) Z C C 900 A M
(3) Z C C 1200 P
(4) L A V L B V $\overline{\text{V A}}$

49. Operation exercise.—*a. First exercise.*—Directions to the student: The net consists of three stations, LA, LB, and LC. The net call sign is ABC. Execute the following communications.

(1) Station LA will ask the other stations of the net (collectively) for a report on the signal strength and readability of station LA.

(2) Stations LB and LC will answer in proper turn. LB will inform LC that his signals are moderately strong but that his readability is poor. LC will inform LA that his signals are moderately weak but perfectly readable.

(3) LB will request a report on his frequency by LA.

(4) LA will inform LB that his frequency in ten kilocycles too low.

(5) LB will simulate adjustment of transmitter to correct the frequency and ask LA to check the frequency again.

(6) LA will inform LB that his frequency is now correct, readability good.

(7) LA will direct LC to send a series of V's.

(8) LC will comply.

(9) LA will inform LC that his frequency is five kilocycles too high.

(10) LC will simulate transmitter adjustment and request frequency check from LA.

(11) LA will inform LC that his frequency is now correct, readability excellent.

(12) LC will inform LA that he has two messages for LA.

(13) LA will request LC to repeat his last transmission.

(14) LC will comply.

(15) LA will direct LC to send the messages.

(16) LC will ask LA if he (LC) should send at a speed of ten words per minute.

(17) LA will tell LC: "Yes."

(18) LA will ask LB is he is in radio communication with FG.

(19) LB will tell LA to wait.

(20) LB will call FG. (No reply from FG.)

(21) LB will call FG again. (No reply from FG.)

(22) LB will inform LA that LB is not in radio communication with FG.

(23) Using the net call-up LA will direct LB and LC to call LA again at 8:30 P.M. on 3900 kilocycles.

(24) LB and LC will acknowledge LA's order.

b. Subsequent exercises.—The instructor will check the logs at this point. After the instructor has done so, the operator originally at station LA will take over station LB, the operator at station LB proceeding to LC and the one at LC going to LA. With this new arrangement of operators, repeat the communications listed in *a*(1) through (24) above.

Section VII

RADIOTELEGRAPH PROCEDURE LESSON III, TACTICAL RADIO NETS

50. Organization of tactical radio nets.—Field radio stations are grouped into separate nets of a few stations each. All operations

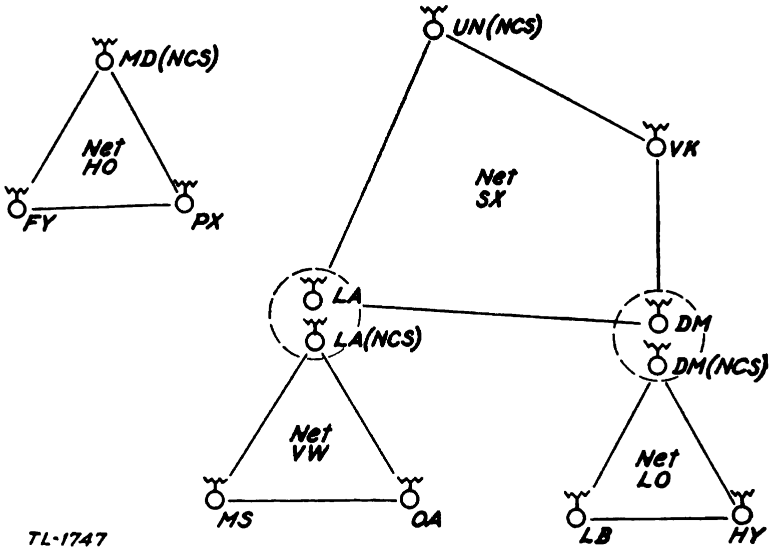

FIGURE 12.—Tactical radio nets.

normally are confined to communications within the individual nets. For purposes of administration, one station, generally the one which is located at the highest headquarters, is appointed net control station (NCS) with authority to direct the net in the control of radio communication. All other stations of the net are referred to as secondary stations. A scheme of tactical radio nets showing net control stations and the normal traffic channels is shown in figure 12. The two stations with the same call sign, LA, are two distinct stations located at the same headquarters. One operates in the net SX on the frequency

assigned to the net SX, and the other operates in the net VW on that net's frequency. The two stations are far enough apart, both in frequency separation and in physical distance, so as not to interfere with each other; and yet they are located close enough together to be cooperative in that each can serve as a relay station for internet traffic.

51. Establishing a net.—*a*. UN, LA, DM, and VK are stations in net SX (figure 12). The net is about to go into operation in a tactical situation. The operators are informed of their call signs and their frequency and of the time when complete communication within the net is expected. They know that UN is to be the NCS. This information, together with other pertinent instructions, appears in signal operation instructions issued to the units concerned.

b. LA, on completing the installation of his station, listens on the assigned net frequency. Hearing nothing, LA calls:

SX V LA ZGQ $\overline{\text{AR}}$

LA repeats the call-up once shortly afterward, and again at intervals as prescribed in paragraph 29*c*:

SX V LA ZGQ $\overline{\text{AR}}$
SX SX SX V LA LA LA ZGQ $\overline{\text{AR}}$

At this point UN has just completed his installation, and, listening on the assigned net frequency, hears LA's call-up. UN answers:

LA V UN ZSB4 ZGQ U $\overline{\text{AR}}$

U means "I am the NCS." And the complete transmission implies "Give me a readability report." LA answers:

UN V LA ZSB5 $\overline{\text{AR}}$

During the above intercommunication DM, completing his installation and listening on the assigned net frequency, overhears UN and LA working together. He waits for them to complete their transmissions and then calls:

UN V DM ZSB4 ZGQ $\overline{\text{AR}}$

UN replies, presuming DM's frequency to be too high:

DM V UN ZFO $\overline{\text{AR}}$

DM makes the necessary adjustments and transmits:

UN V DM ZFM $\overline{\text{AR}}$

UN replies:

DM V UN ZFN ZSB4 ZWG LA U K

ZWG means: "The following stations (in addition to UN and DM) are in the net: LA." UN concludes with K because he wants a receipt for the transmitted information. DM complies:

UN V DM R

DM now calls LA to exchange readabilities.

LA V DM ZSB5 $\overline{AR}$
DM V LA ZSB4 $\overline{AR}$

VK, completing his installation several minutes later, listens on the assigned frequency but hears no signals being transmitted at the time. He calls:

SX V VK ZGQ $\overline{AR}$

UN answers, assuming VK's frequency to be low:

VK V UN ZFP $\overline{AR}$

VK adjusts his transmitter and continues:

UN V VK ZFM $\overline{AR}$

UN replies:

VK V UN ZFN ZSB5 ZWG LA DM U ZSG $\overline{AR}$

VK answers:

UN V VK ZSB4 $\overline{AR}$

VK, now knowing that LA and DM also are in the net, calls these stations to exchange readabilities:

LA V VK $\overline{AR}$
VK V LA ZSB4 $\overline{AR}$
LA V VK ZSB3 $\overline{AR}$
DM V VK $\overline{AR}$
VK V DM ZSB5 $\overline{AR}$
DM V VK ZSB5 $\overline{AR}$

It is to be noted that UN has caused LA, DM, and VK to adjust their transmitters until all three stations came in at the same tuner dial setting on UN's receiver. Now in order to insure that his (UN's) signals come in at the same place as the other stations' signals on any of the other receivers, UN calls up one station, say LA, and requests:

LA V UN ZFM $\overline{AR}$

LA checks his receiver dial setting against the position where he receives DM and VK, and, presuming that UN's indicated frequency is high, advises UN accordingly:

UN V LA ZFO $\overline{AR}$

UN adjusts his transmitter to conform and sends:

LA V UN ZFM $\overline{\text{AR}}$

LA replies:

UN V LA ZFN ZSB4 $\overline{\text{AR}}$

The four stations are now in communication with each other and are ready to exchange traffic.

c. In establishing the net, in case the regular NCS is late in reporting in, the first station entering the net acts as NCS and so informs the other stations by means of the procedure signal ZGD. The use U is confined to the regularly appointed NCS.

52. Leaving the net; internet traffic.—*a.* Whenever the NCS withdraws from the net, he appoints a substitute to act in his absence:

LA V UN ZGB THIRTY MIN ZGR K (Take over NCS duties for 30 minutes. I am leaving the net.)

or

LA V UN ZGB THIRTY MIN ZGR LB 3890 K (Take over NCS duties for 30 minutes. I am leaving to communicate with LB on 3890 kilocyles.)

LA acknowledges:

UN V LA R $\overline{\text{VA}}$

A secondary station which wishes to leave the net to transmit a message to a station in another net must first report to the NCS of its own net, indicating the station with which it intends to communicate. Thus:

UN V VK ZGR PX $\overline{\text{AR}}$

Further, any station calling a station in another net must report in to the NCS of the net being entered, and then finally report out again at the conclusion of the transaction of the internet traffic:

MD V VK ZGQ ZMA ONE PX $\overline{\text{AR}}$
VK V MD K
PX V VK $\overline{\text{AR}}$
VK V PX ZSB4 K
PX V VK ZSB4 $\overline{\text{XE}}$ ——— (message) ——— **K**
VK V PX R $\overline{\text{VA}}$
MD V VK ZGR $\overline{\text{AR}}$

VK reenters his own net just as he did upon initially entering the net. He exchanges readabilities with all other stations in the net and adjusts his frequency in accordance with UN's directions.

b. In the case of VK having traffic for OA (see fig. 12), this could be handled in a fashion similar to that in *a* above, or, if desired, VK could here make use of the relay services of LA.

c. The only exception permitted to the procedure described in *a* and *b* above for the exchange of internet traffic is in the handling of urgent messages. These are dispatched in any expedient manner, through direct call-up if practicable, to insure the fastest transmission possible.

53. Directed net.—If operation of the net is not progressing smoothly, as, for instance, if two stations are monopolizing the net frequency by continued transmissions, preventing the flow of other traffic in the net, the NCS may exercise close control by ordering a directed net:

SX V UN ZGT ONE ZMW K

The K indicates that UN wants a receipt of the directed-net order, as well as a report of the traffic on hand. The secondary stations answer:

UN V DM R ZMA ZERO $\overline{\text{AR}}$

UN V LA R ZMA TWO DM $\overline{\text{XE}}$ ONE VK $\overline{\text{AR}}$

(Two routine messages for DM; one routine for VK)

UN V VK R ZMA THREE LA $\overline{\text{AR}}$

UN directs:

LA V UN K (Send all traffic which you reported)

As long as the net is directed, each station reports to the NCS as it acquires new traffic to transmit and then awaits direction from the NCS before proceeding, except that immediately upon receipt of an urgent message from his message center, the operator will break in on any transmission, except the transmission of another urgent message, and clear the urgent traffic directly to the station of destination without preliminary permission of the NCS. To restore the net to free operation the NCS transmits:

SX V UN ZGT TWO K

This is receipted for in the regular order by the secondary stations.

54. Silence restriction.—As a control measure, or for other reasons, the NCS may silence an individual station of the net (or the whole net) by addressing the silence procedure sign, sent five times to that station (or to the whole net):

DM V UN $\overline{\text{HM}}$ $\overline{\text{HM}}$ $\overline{\text{HM}}$ $\overline{\text{HM}}$ $\overline{\text{HM}}$ $\overline{\text{AR}}$

$\overline{\text{HM}}$ transmitted five times and followed by a procedure sign designating a class of traffic means: "Cease all transmission except for class of traffic indicated."

DM V UN $\overline{\text{HM}}$ $\overline{\text{HM}}$ $\overline{\text{HM}}$ $\overline{\text{HM}}$ $\overline{\text{HM}}$ O $\overline{\text{AR}}$

$\overline{\text{UO}}$ transmitted five times means: "Silence restriction removed." Neither $\overline{\text{HM}}$ nor $\overline{\text{UO}}$ is ever receipted for.

55. Closing the net.—The NCS orders the closing of the net by use of the procedure signal ZWA:

SX V UN ZWA K

The use of K indicates that UN wants the net stations to receipt for the instructions to close the net.

The secondary stations receipt in order:

UN V DM R $\overline{\text{VA}}$
UN V LA R $\overline{\text{VA}}$
UN V VK R $\overline{\text{VA}}$

56. Procedure signals.—The following procedure signals with their meanings should be memorized.

Classification	Procedure signal	Meaning
G: Net control	ZGB	Take over radio guard or net control for (until ———).
	ZGC	Are you (or is ———) radio guard or net control station for ——— (on ——— kc.). (In the second blank indicate either net call sign or station call sign.)
	ZGD	I am (or ——— is) radio guard or net control station for ——— (on ——— kc.).
	ZGQ	Station reports into net.
	ZGR	Station leaves net temporarily (or for ——— hours) (to communicate with ———) (will be on ——— kc.).
	ZGT	Net is ——— (1. Directed; 2. Free).
T: Time and transmissions.	ZTJ	Transmit only urgent or priority messages.
W: Stations	ZWA	Close or secure (or direct ——— to close or secure) your (his) station or watch (on ——— kc.).
	ZWG	Following stations are keeping watch on ——— kc. (or are in net).

57. Questions for self-review.—Refer to figure 12 in conjunction with these questions.

a. PX is the first station to be set up in the net HO, MD is the second, and FY is the last. Indicate all transmissions in order of occurence in establishing the net. Presume all signals ZSB4 and frequencies correct.

b. Repeat the above for the case of FY's frequency being high, the others being correct.

c. What station acts as NCS until the NCS reports into the net?

d. HY wishes to leave his net to communicate with VK. Show all transmissions in order of occurrence involved in HY's exchange of traffic with VK and ultimate return to the original net.

e. What information does each station furnish the NCS in compliance with an order from the NCS for a directed net?

58. Operation exercise.—*a. First exercise.*—The net consists of three stations, FY, PX, and MD, with net call sign HO. MD is the NCS. Proper acknowledgment will be made for all transmissions whenever appropriate in the operations below. Readabilities will be exchanged and frequencies adjusted as necessary each time a new station enters the net.

(1) The NCS will open a free net.
(2) Secondary stations will report into the net in order of call signs.
(3) PX will report out of the net to transmit a message to OA.
(4) The NCS will report out of the net temporarily.
(5) PX will report back into the net.
(6) The NCS will return to the net.
(7) The NCS will order a directed net.
(8) The NCS will impose the silence restriction upon PX.
(9) The NCS will close the net.

b. Subsequent exercises.—The instructor will check the logs at this point. After the logs have been checked, repeat operations *a*(1) through (9) above with FY acting as NCS and MD being one of the secondary stations.

SECTION VIII

RADIOTELEGRAPH PROCEDURE LESSON IV, THE ABBREVIATED FORM MESSAGE

59. Form of message.—*a. General.*—Army radio messages are of two types. One, a "streamlined" style designed for speed in transmission of tactical messages, is known as the "abbreviated form". Its use is required within divisions and by smaller units and in all

communications involving air elements. The other type of message, known as the "normal form", is designed for use by headquarters above division. In addition to a difference in the form of the two types of messages, there is some difference in the procedure for handling them. This lesson is devoted principally to the abbreviated form message and its handling. The normal form message is treated in section X.

b. Abbreviated form.—The following is an example of an abbreviated form message with its various components labeled:

$$\underbrace{\overbrace{\text{LA V LB}}^{\text{Call}}\quad \overbrace{\text{T KL V FX}}^{\text{Retransmission instructions}}\quad \overbrace{\text{G}}^{\text{Special operating instructions}}\quad \overbrace{\text{O}}^{\text{Classification}}\quad \overbrace{\overline{\text{BT}}}^{\text{Break}}}_{\text{Heading}}$$

$$\underbrace{\text{DFC4 ALPX DGYR}\ \overbrace{\text{923A}}^{\text{Time of origin}}}_{\text{Text}}\qquad \overbrace{\text{K}}^{\text{Terminating sign}}$$

The retransmission instructions to LA, viz., T KL V FX, are interpreted: "Transmit the following to KL from FX." The special operating instruction G means "Repeat back". The classification O means "Urgent". The complete message above extends from the call to the time of origin, inclusive. If, for instance, it is requested that the message be repeated, everything shown above is repeated.

60. Classification of messages.—Abbreviated form messages are designated as either urgent or routine; there are no other classifications. An urgent message carries the classification procedure sign O in the heading. No classification designation is carried on routine messages. An urgent message is given utmost precedence, never being delayed except for the transmission of other urgent traffic. The handling of routine traffic is interrupted in order to transmit an urgent message.

61. Identification of messages.—The station of origin and the time of origin serve to identify a message for any future reference. The message in paragraph 59*b* may be referred to as FX 923A or, if the station of origin is understood, simply as 923A. To illustrate abbreviated form message identification by station and time: One station might ask another, FX923A R $\overline{\text{IMI}}$, meaning "Have you received the message which originated at FX at 923A?"

62. Retransmission and special operating instructions.—Retransmission and special operating instructions do not appear on every message transmitted.

a. Relaying messages.—The message shown in paragraph 59*b* illustrates the special operating instructions required for directing the relay of a message. The station in a relay chain which finally forwards the message to the station of destination obviously omits the procedure sign T which means "Retransmit". Thus when LA forwards the abbreviated form message shown in paragraph 59*b* to the addressee, KL, LA transmits:

KL V LA $\overline{\text{XE}}$ KL V FX G O $\overline{\text{BT}}$
DFC4 ALPX DGYR 923A K

It may so happen that in receiving the message from LB, LA misses the group DGYR and then for some reason (possibly faded signals) is unable to contact LB again at that time for a repeat request. LA does not delay the relaying of the message on account of this missing group, but transmits as follows to KL:

KL V LA $\overline{\text{XE}}$ KL V FX G O $\overline{\text{BT}}$
DFC4 ALPX $\overline{\text{AA}}$ 923A K

The $\overline{\text{AA}}$ signifies that a group is missing at this place in the message. As soon as possible LA obtains the missing group from LB and passes it on to KL. If the text of the message under discussion were included in a routine message transmitted from FX directly to KL, with no special operating instructions, the message would appear:

KL V FX $\overline{\text{BT}}$ DFC4 ALPX DGYR 923A K

b. Repeat back.—(1) To definitely insure correct reception, the transmitting operator of the message illustrated in paragraph 59*b* has ordered a repeat back by use of the procedure sign G.[1] LA repeats back to LB as follows:

LB V LA $\overline{\text{XE}}$ LA V LB T KL V FX
G O $\overline{\text{BT}}$ DFC4 ALPX DGYR 923A $\overline{\text{AR}}$

LB underscores each group repeated back correctly and acknowledges:

LA V LB C (Correct)

Or, if this is the only or last message sent by LB:

LA V LB C $\overline{\text{VA}}$

The original message is not considered as properly received until the transmitting operator sends this C. When repeating back or correcting repeat backs, each group is sent only once, notwithstanding that each group may have been sent twice in the original transmission. Any relayed message bearing the instructions G is repeated back by

[1] In Joint Army and Navy operations, ZPG is used instead of G.

each receiving station which handles the message. The message illustrated in paragraph 59*b* advances in the order FX–LB–LA–KL. LB repeats it back to FX on receiving it from FX; LA repeats it back to LB on receiving it from LB; and KL repeats it back to LA on receiving it from LA.

(2) An operator may request a repeat back of any previously sent message by transmitting G together with proper identification of the message. Thus:

NA V NB G 713A $\overline{\text{AR}}$
NB V NA $\overline{\text{XE}}$ NA V NB $\overline{\text{BT}}$ VUBO ABYZ 713A $\overline{\text{AR}}$
NA V NV C

63. Transmitting messages in strings.—When radio communication is good, it frequently facilitates the handling of traffic for one station to send several messages to another without interruption. The receiving station might request ZOD THREE: "Transmit your messages in strings of three." The transmitting station separates the messages with the sign $\overline{\text{AR}}$ [1]:

LA V LB $\overline{\text{BT}}$ TMST LTHJ 930P $\overline{\text{AR}}$ LA V LB $\overline{\text{BT}}$
LDFX ORZY 941P $\overline{\text{AR}}$ LA V LB $\overline{\text{BT}}$ LOUX
946P K

When the receiving operator hears the K he knows the string is finished and that he is expected to receipt for the messages. The receiving station acknowledges.

L B V LA R 930P $\overline{\text{XE}}$ 941P $\overline{\text{XE}}$ 946P $\overline{\text{AR}}$

64. Copying and servicing.—*a. Copying.*—Typewritten copy is made either five or ten groups to the line; penciled copy, five groups to the line. The receiving operator does not copy the complete call in a message as it is transmitted, but records only the call sign of the transmitting station. This information, together with retransmission and special operating instructions and the message classification, is entered on the message blank at the top near the word "Message." Figure 13 shows the receiving operator's original copy of the message corresponding to the following transmission:

LA V LB T KL V FX G O $\overline{\text{BT}}$
NR13 CD GOXDR FADUL KIJEY
NAMIH LAEDG PRYNO CAJIN ZEDBL
DOFIN AWENJ 957A K

[1] The transmitting station will allow 15 seconds between messages sent in strings. All operators will listen during this silent period in order that any urgent traffic may be cleared.

440750°—42——4

THESE SPACES FOR MESSAGE CENTER ONLY

TIME FILED	MSG CEN No	HOW SENT

LB T KL V FX **MESSAGE** G O
(SUBMIT TO MESSAGE CENTER IN DUPLICATE)

No ________ DATE ________

To

NR13 CD GOXDR FADUL KIJEY

NAMIH LAEDG PRYNO CAJIN ZEDBL

DOFIN AWENJ 957A

1Ø15A X

OFFICIAL DESIGNATION OF SENDER | TIME SIGNED

SIGNATURE AND GRADE OF WRITER

TL-2187

FIGURE 13.—Abbreviated form message copies on message form.

The receiving operator copies all messages in duplicate. The first line of the text is copied on the line below the line beginning with the word "To." Succeeding lines of text are copied on alternate lines of the message form to enable handling personnel to read the text more easily. Unless otherwise specified in the text of the message, the writer and the addressee are indicated by the call signs of the station of origin and the station of final receipt and are the commanding officers of the units which these stations serve. The first group of the text, NR13, is a number group which is composed of the two letters NR and the number which the writer assigned to the message as a means for his future identification of the message. This number may or may not appear on messages in either the abbreviated or normal form. The blank following "No" on the message form is for use with the normal form message only and is properly filled with a serial number assigned by the radio station of origin and serves as a means of future identification of the message for that radio station. The blank following "Date" on the message form is for use with the normal form message only and is filled with

the date of the day on which the message was filed with the message center. This date when inserted as part of the heading of a normal form message is spelled out; for example, "Fifteenth," and the month and year are *not* written on the blank containing the message. The blank following "To" is reserved for use of the message center, as are also the blanks following "Time filed," "Msg Cen No," and "How sent" at the top of the message form.

b. Receiving operator's service.—The notation 1015A X is called the receiving operator's "service." X is the receiving operator's personal sign. 1015A is the time the message was receipted for by the receiving operator, that is, the time at which the message was considered as completely and correctly received. The receiving operator encircles his service as shown in figure 13 to indicate definitely that the service is not part of the text.

c. Transmitting operator's service.—The transmitting operator services his copy of the message by entering the time of receipt and his personal sign at the bottom of the message. In addition he indicates the station to which the message was sent, in the event that this information is not already noted on the message blank. Many operators perform this service with one hand while operating the key with the other.

65. Requests for repetitions.—*a. Use of $\overline{\text{IMI}}$.*—The manner in which a receiving station requests repeats for all or parts of a message is given below. Consider the original transmission to have been:

BC2 V CA O $\overline{\text{BT}}$ DFC4 XPST ROYM ACZU FVLN PKGZ QEBD HJOW 610P K

Should BC2 desire a repetition of the entire message, he transmits:

CA V BC2 $\overline{\text{IMI}}$ $\overline{\text{AR}}$

CA then repeats the entire message. Had BC2 missed any portion of the heading, he must request a repetition of the entire heading:

CA V BC2 $\overline{\text{IMI}}$ AB $\overline{\text{BT}}$ $\overline{\text{AR}}$ (Repeat all before $\overline{\text{BT}}$.)

To which CA replies:

BC2 V CA $\overline{\text{XE}}$ BC2 V CA O $\overline{\text{BT}}$ $\overline{\text{AR}}$

This transmission includes the $\overline{\text{BT}}$ itself, as well as everything before the $\overline{\text{BT}}$. For any other repeat requests, BC2 makes judicious use of AB (all before), AA (all after), WA (word after), and GR (text group number). For example, desiring a repeat of the time of origin, BC2 might have transmitted either of the following:

CA V BC2 $\overline{\text{IMI}}$ WA HJOW $\overline{\text{AR}}$

or

CA V BC2 $\overline{\text{IMI}}$ AA HJOW $\overline{\text{AR}}$

Responses to the above requests would be respectively:

B C 2 V C A H J O W 610P $\overline{\text{A R}}$
B C 2 V C A H J O W 610P $\overline{\text{A R}}$

Note that in each case the originating station repeats the last group received correctly as well as that portion requested. For a repetition of all between DFC4 and FVLN, the request is as follows:

C A V B C 2 $\overline{\text{I M I}}$ D F C 4 T O F V L N $\overline{\text{A R}}$

CA replies:

B C 2 V C A D F C 4 X P S T R O Y M A C Z U F V L N $\overline{\text{A R}}$

Note that the originating station repeats the correctly received end groups as well as intervening portions requested. It is possible that a group to which reference is made appears elsewhere in the same text, Consider the following transmission:

O G 3 V M Y 9 $\overline{\text{B T}}$ OBSERVER GUNNER AND PILOT OF ENEMY BOMBER CAPTURED AND BEING HELD PENDING ARRIVAL OF INTERPRETER 957A **K**

Having missed everything after OF, the fifth word of the text, OG3 requests:

M Y 9 V O G 3 $\overline{\text{I M I}}$ A A P I L O T $\overline{\text{A R}}$

Had OG3 requested simply $\overline{\text{IMI}}$ AA OF, MY9 would not have known whether to begin his repeat with OF ENEMY or with OF INTERPRETER. In a message with a long text a particular group referred to by the receiving operator might be difficult for the transmitting operator to locate readily. In such a case repetitions are facilitated by numbering the text groups in sequence and referring to any particular group by both its number and the group itself. For example, $\overline{\text{IMI}}$ AA GR19 ADQC requests a repetition of all groups after ADQC, ADQC being group number 19; or $\overline{\text{IMI}}$ GR19 ADQC TO SUMC requests a repetition of all groups between ADQC, which is number 19, and SUMC. Whenever the receiving operator is uncertain of the ordinal number of a group, as is the case if he has missed an unknown number of preceding groups, it will be necessary to refer to the group alone without number as was done above with SUMC: $\overline{\text{IMI}}$ ADQC TO SUMC.

b. Break-in operation.—Break-in operation, in which the receiving operator may interrupt the transmitting operator at any time, is authorized, and its use will be explained later. However, since break-in operation is not possible with many types of field radio equipment, all requests for repetitions during this preliminary training period will be conducted as indicated in *a* above.

66. Procedure signs and procedure signals.—*a. Procedure signs.*

Procedure sign	*Meaning*
A A	All after.
A B	All before.
$\overline{\text{B T}}$	Break.
C	Affirmative. Correct.
G	Repeat back.
G R	Group.
O	Urgent.
T	Transmit (to).
W A	Word after.

b. Procedure signals.

Classification	Procedure signal	Meaning
O: Operating	Z O D	Transmit your messages in strings of ------.
	Z O E	I am going to transmit my messages in strings of ------.

67. Questions for self-review.— *a.* In the transmission shown below indicate the following: message, text, time of origin, call, special operating instructions, retransmission instructions, break, heading, station of origin, station of destination, and terminating procedure sign.

JK V FG T KL V FG G O $\overline{\text{BT}}$ ATTACK AT ONCE 820A K

b. How does the transmitting operator indicate that a message is urgent? Routine?

c. In the message shown in question *a* above, if JK had missed the word ATTACK, how would he request a repetition to obtain this word? How would he request a repetition of the operating instructions? Of the complete text?

d. With reference to a G message should the service time be that at which the originating station transmits K, that at which the receiving station completes the repeat back, or that at which the originating station transmits C? Why?

e. What procedure sign is used to separate messages sent in strings?

f. Show the receiving operator's acknowledgment for reception of the following three messages sent in a string: 1210A, 1215A, 1222A.

g. How many groups are printed per line in reception?

h. Why is the text of the message copied on alternate lines?

i. Does a receiving operator record anything on the line of the message blank marked "To"? Why?

68. Operation exercise.—A net consists of three stations, LA, LB, and LC, with net call sign LX. LA is the NCS. The NCS will open a free net. No readability will be below ZSB4. Traffic will be exchanged in the following order:

To	From	Retransmission instructions	Special operating instructions	Remarks
LB	LC	None	None	Single message.
LC	LA	None	G O	LA sends to LC; LC repeats back to LA.
LA	LB	None	None	Single message.
LC	LB	T LA V LB	O	LB sends to LC; LC relays to LA.
LB	LA	None None	None None	Two messages in string.
LA	LC	None T LB V LC	O G	LC sends two messages to LA in string; LA repeats back second message and then relays this second message to LB; LB repeats it back to LA.

Section IX

RADIOTELEGRAPH PROCEDURE LESSON V, THE ABBREVIATED FORM MESSAGE, CONTINUED

69. Acknowledgment by addressee.—The writer of a message may require personal acknowledgment by the addressee of receipt of a message. In this case the transmitting operator includes the procedure sign Y ("Acknowledge") in the special operating instructions in the heading of the message. Example:

JK V FG Y O $\overline{\text{BT}}$ DFC4 PLIX FOAM 1030A K

JK receipts for correct reception in the usual manner:

FG V JK R

When the message is delivered to the addressee, he is informed that an acknowledgment is requested. The addressee, after he has received and understood the message, notifies his message center that the message is to be acknowledged. When JK is so informed, he transmits:

FG V JK O $\overline{\text{BT}}$ FG 1030A 1045A K

The above acknowledgment is a regular message. 1045A is the time of origin of the message; in other words, it is the time of the acknowledgment by the addressee. The text of the acknowledgment message, viz., FG 1030A 1045A, means: "The message which was originated at FG at 10:30 A. M. has been acknowledged by the addressee at 10:45 A. M." An operator receiving such an acknowledgment forwards the acknowledgment message to his message center just as he has copied it. The message center interpolates its text to read: YOUR MESSAGE OF 10:30 A. M. HEREBY ACKNOWLEDGED. The signature on the above message is that of the commanding officer of the tactical unit to which JK belongs; the addressee is the commanding officer of the tactical unit to which FG belongs; and the ultimate recipient is the individual who wrote the original message which is being acknowledged. The acknowledgment carries the same classification as the original message. An original urgent message receives an urgent acknowledgment; an original routine message, a routine acknowledgment.

70. Check with originating message center.—In case a received message appears incoherent when decoded, a check with the station from which the message was received may be directed by the message center of the receiving station. Having been directed to obtain such a check, the radio operator of the receiving station employs the procedure signal ZMX: "Verify the message or portion thereof indicated with your message center (communication office) and transmit correct version." EF, having receipted for an abbreviated form message with a time group 1130A from DD, later is requested by his (EF's) message center to secure a check and repetition of a portion of the message. EF transmits:

DD V EF ZMX DD 1130A NUGWH TO APDWT K

DD transmits:

EF V DD R

And then DD refers this questionable portion to his message center for check. DD's message center locates the error in the original encoding

and gives the correct coded version to the radio operator, who transmits:

EF V DD C DD 1130A NUGWH WIGSO ZLAYS APDWT K

C DD 1130A means: "The following is the correct version of a portion of a message originated at DD at 11:30 A. M." In reply to a request for a check and repeat of the complete message, DD would transmit:

EF V DD C EF V DD $\overline{\text{BT}}$ NR76 CD NUGWH WIGSO ZLAYS APDWT ZOTQB ITBQW RLUMN 113ØA K

In this last transmission a reference to the station and the time of origin preceding the message is unnecessary, since this information appears in the message. Requests for check of specific portions of a message are made in a manner corresponding to that for which requests are made for ordinary repetitions, using ZMX in the former case where $\overline{\text{IMI}}$ is used in the latter. Thus, whereas a repetition of the complete text of a message is requested by transmitting $\overline{\text{IMI}}$ AA $\overline{\text{BT}}$, a check of a text by a message center is requested by transmitting ZMX AA $\overline{\text{BT}}$.

71. Verification by the writer.—The addressee may direct that all, or a part, of the contents of a message be verified by the writer. EF, having received an abbreviated form message from DD with a time group 1130A, later is directed by the addressee at EF's unit to secure a verification and repetition of a portion of the message. EF transmits:

DD V EF J DD 1130A HIHO TO SAPV K

DD transmits:

EF V DD R

And then DD's message center refers this questionable portion (properly decoded) to the originator for verification. The verified original or altered version is transmitted:

EF V DD C DD 1130A HIHO DANY MASU SAPV K

C DD 1130A means: "The following is the correct version of a portion of a message originated at DD at 11:30 A. M." The procedure is entirely analogous to that used for checking errors within the signal network, replacing ZMX with J.

72. Correction initiated by originating station.—It is possible that an originating station may detect an error in a message previously transmitted, and for which a receipt has already been obtained. For example, consider that EF has transmitted as a part of a message: NUGWH NOZIQ LPURT APDWT. EF some time later discovers

that the groups NOZIQ LPURT are incorrect and should have been WIGSO ZLAYS. EF transmits:

DD V EF CCCC EF 1130A NUGWH WIGSO ZLAYS APDWT K

including the overlapping groups NUGWH and APDWT which were previously sent correctly. This means to DD: "Herewith a correct portion of a message originated at EF at 11:30 A. M. Correct the message accordingly." The four C's serve to direct definitely the receiving operator's attention to the fact that the transmission following is a correction originated by the transmitting station.

73. Transmitting to a silent station.—A station whose transmitter is inoperative can receive messages by radio but must acknowledge receipt of the message by other signal means if such are available. To increase a silent station's chances of receiving a radio message intended for it, the message is generally transmitted twice.

a. "F" method.—One way of transmitting to a station when a radio reply is forbidden or impossible is the direct, or "F", method. F means "Do not transmit. Do not answer." The transmitting station sends all calls, groups, procedure signs, with the exception of V, twice, and terminates with $\overline{\text{VA}}$.

Example:

DB DB V DA DA F F $\overline{\text{BT}}$ $\overline{\text{BT}}$ VOBU VOBU 1235P 1235P $\overline{\text{VA}}$ $\overline{\text{VA}}$

b. Intercept method.—A second method is the "intercept" or "I" method. By prearrangement, messages whose contents are intended for a silent station can be exchanged between two regularly operating stations. For example, EF might transmit a message to EG. The message center at EG, on decoding the message, learns from its contents that it is intended for a third station, EH, and EG takes no further action on the message. EH, however, gets the message by "eavesdropping" when it is transmitted from EF to EG. In this way the enemy may be kept in ignorance of the existance of a station at EH at least until such time as EH begins transmitting. To assist EH's reception of messages by the intercept method, those messages which are intended for EH may be confined to the G messages in the net. In this way EH has two opportunities for copying each message, once when it is first transmitted and a second time when it is repeated back. Further, EH is not obligated to copy and decode all the messages in the net, but only the G messages.

74. Messages of execution.—The procedure sign $\overline{\text{IX}}$ transmitted just before the $\overline{\text{BT}}$ sign means: "The message following is a prepara-

tory command and is not to be acted upon until the execute sign is received." Example:

NA V EF $\overline{\text{IX}}$ BT ATTACK **630A K**

This message means: "Prepare to attack. A signal of execution will follow shortly." The message is acknowledged:

EF V NA R

Then, until the signal of execution is transmitted, no transmissions whatsoever will be made in the net other than such as pertain directly to the preparatory order just issued, for example, a revoking order by EF or the signal of execution itself. The signal of execution is $\overline{\text{IX}}$ followed by a five-second dash:

NA V EF $\overline{\text{IX}}$ 5-second dash.

This message is not acknowledged. In the event that there may not be sufficient time intervening between the preparatory order and the signal of execution to permit a receipt for the former, EF concludes the preparatory order with $\overline{\text{AS}}$ instead of with K:

NA V EF $\overline{\text{IX}}$ BT ATTACK **630A $\overline{\text{AS}}$**

NA does not receipt but awaits the next transmission from EF. (The student should practice making five-second dashes. Individuals who have not definitely trained themselves to perceive time intervals usually have a surprisingly poor concept of the duration of seconds.)

75. Break-in operation.—If the radio equipment in the net is of a type permitting break-in operation, one station may interrupt another by making long dashes. To illustrate: BC, while receiving a message from EF, misses the group after ABYZ. BC transmits a series of long dashes until EF stops, at which time BC transmits:

ABYZ K

EF resumes his transmission with the group ABYZ:

ABYZ BZXY CDWX 630A K

If BC encounters temporary interference which blankets EF's signals, making reception impossible, BC transmits a series of long dashes until EF stops, at which time BC transmits:

$\overline{\text{AS}}$

BC repeats $\overline{\text{AS}}$ every 30 seconds until the interference has sufficiently subsided and then directs that EF continue from the last group which BC has correctly received, say ZYNO, by transmitting:

ZYNO K

76. Procedure signs and procedure signals.—*a. Procedure signs.*

Procedure sign:	*Meaning*
F	Do not transmit. Do not answer.
$\overline{\text{IX}}$	Execute to follow.
J	Verify and repeat.
Y	Acknowledge.
$\overline{\text{IX}}$ 5-second dash	Execute.

b. Procedure signals.

		Meaning
M: Messages	ZMX	Check the message or portion thereof indicated with your message center (communication office) and transmit correct version.

77. Questions for self-review.—*a.* How does a transmitting operator indicate to the receiving operator that the writer of a message desires a personal acknowledgment from the addressee?

b. If at 7:25 A. M. the addressee acknowledges an abbreviated form message BC2 711A, show the message of acknowledgment which is actually transmitted.

c. What procedure signal is used to request a check with the message center of origin?

d. Show the transmission sent to the station of origin from BC2 to obtain the writer's verification on an abbreviated form message BC1 515A.

e. Show the transmission from the station of origin to BC2 to indicate that the writer of an abbreviated form message BC1 329A verifies the group after HIHO as DANY.

f. EF has sent the following message to BC:

BC V EF BT ADVANCE TO CONEWAGO **102A K**

A few minutes later EF's message center discovers that the word TO in the above message should have been ON and directs EF to correct the message. Show EF's transmission to BC.

g. How is an F message terminated? Why?

h. What is the principal advantage of the intercept method over the F method for transmission to a silent station? Give one advantage of the F method over the intercept method.

i. How is the following transmission interpreted:

LA V LB $\overline{\text{IX}}$ $\overline{\text{BT}}$ FIRE MIDNIGHT **K**

j. Do stations report into the net anew in the event of a change of call signs during net operation?

78. Operation exercise.—Radio stations in this exercise are those of the 4th Infantry and of the 1st, 2d, and 3d Battalions, 4th Infantry. The 2d Battalion station is a silent station. Student operators assigned to these units will refer to the signal operation instructions shown in FM 24-5 for their call signs. Consider the date as December 1, 1938. (If FM 24-5 is not available, the instructor will supply each student with some form of signal operation instructions.) The instructor will prescribe the traffic to be handled and will order checks, verifications, acknowledgments, and corrections as desired. Messages of execution will be included.

Section X

RADIOTELEGRAPH PROCEDURE LESSON VI, THE NORMAL FORM MESSAGE

79. Variation from abbreviated form.—*a. General.*—The normal form message differs from the abbreviated form message principally in that the former includes the additional features of a text group count (total number of groups in the text), a station-to-station serial number, and a date in the heading. A further distinction is in the classifications of the messages. Abbreviated form messages are classified simply as either urgent (O) or routine, whereas normal form messages are divided into four groups: urgent (O), priority (P), routine, and deferred (D), in descending order of precedence. Handling of the two forms of messages, differs in certain details. These differences are illustrated in this lesson.

b. Precedence of handling.—(1) Urgent messages (O) are transmitted immediately upon receipt except when communication involving another urgent message is being carried on. Thus, the transmission of a deferred, routine, or priority message is interrupted for the transmission of an urgent message.

(2) Priority messages (P) are sent in the order received but before such routine or deferred messages as may be waiting to be sent. The transmission of a message usually is not interrupted to send a priority message.

(3) Routine messages are sent in the order received but before such deferred messages as may be waiting to be sent. The transmission of a deferred message is not interrupted to send a routine message.

(4) The deferred classification (D) is used for those messages whose delivery to an addressee may be delayed until the beginning of office hours on the morning following the day on which they are filed. Although deferred messages are sent ordinarily after routine messages, they must be delivered by the beginning of office hours, which means that under some circumstances they must be sent ahead of routine messages. However, no deferred message is sent ahead of a priority message.

80. Form of the message.—A specimen normal form message with the various components noted is illustrated below:

Heading:

Call	Station-to-station serial number	Retransmission instructions	Special operating instructions
E O 2 V B C 3	N R 2	T AK1 V B C 3	G Y

Classification	Group count	Date	Break
P	G R 10	F I F T H	$\overline{\text{B T}}$

Writer's serial number	Code identification	Text							Time of origin	Terminating sign
N R 6	D F C T 1	A L P X	D G R Y	Q W R C	H J V J	K L G Y	H Y T R	D J Y R	818A	K

If the same text were included in a routine message sent direct to AK1 from BC3 with no special operating instructions, the message would appear:

Heading:

Call	Station-to-station serial number	Group count	Date	Break
A K 1 V B C 3	N R 2	G R 10	F I F T H	$\overline{\text{B T}}$

Writer's serial number	Code identification	Text							Time of origin	Terminating sign
N R 6	D F C T 1	A L P X	D G R Y	Q W R C	H J V J	K L G Y	H Y T R	D J Y R	818A	K

81. Group count.—Any connected group of transmitted characters in the text is counted as one group, each operator being careful to preserve the manner of separating groups as they are originally written. Thus if an originator of a message chooses to write TWENTY ONE (two words), this expression should reach the addressee as TWENTY ONE (two words) and not as TWENTYONE (one word) Obviously, considerable care must be exercised in both transmission and reception to maintain the separations between groups as they properly occur. Examples:

Group:		*Counted as*—
	DG8F	One word
	DG 8F	Two words
	630A	One word
	NR14	One word
	NEWYORK	One word
	NEW YORK	Two words
Thirty-first is sent either	THIRTY FIRST	Two words
	THIRTYFIRST	One word

82. Station-to-station serial number.—The station-to-station serial number is the normal form message identification. EO2 V BC3 NR2 in the heading of the message of paragraph 80 means "message number 2 from BC3 to EO2." BC3 assigns a number 1 to the first message of the radio day which this station transmits to EO2, a number 2 to the second message it transmits to EO2, etc. Further, BC3 assigns a number 1 to the first message of the radio day which it transmits to AK1, a number 2 to the second message it transmits to AK1, etc. With the number and the station to which the message is sent, BC3 uniquely identifies each message it transmits. In a similar manner in its records of received messages, BC3 identifies each message it receives as the third for the radio day from EO2 or the fifth from BC1, etc. If it is desired to send the same message to two or more stations simultaneously, a separate station-to-station serial number is included in the heading for each individual station in the following manner:

OR2 CB2 V AB3 $\overline{\text{XE}}$ OR2 NR8 $\overline{\text{XE}}$ CB2 NR3 GR5 FOURTEENTH $\overline{\text{BT}}$ VUBO ABYZ BCXY CDWX 807P K

The station-to-station serial number changes as a message passes through the various links of a relay system. Each station transmitting the message assigns it a number appropriate to that station's own records. In referring to a message of some preceding date, the date is included along with the serial number, as NR7 TWENTYFIRST.

83. Operator's number sheet.—Records of messages handled are kept on the operator's number sheet. A sample number sheet is shown in figure 14. Entries are made according to the instructions printed at the top of the number sheet. A line drawn through

W. D., Sig. C.
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SIGNAL CORPS, UNITED STATES ARMY

OPERATOR'S NUMBER SHEET

Check off both sent and received numbers immediately and enter time and personal sign. Numbers must be exchanged nightly at closing hour. Receiving and sending operators will be held responsible for correct records of numbers.

STATION MS, 6Ø3RD DIV CIRCUIT OR NET FGG, 6TH CORPS DATE 1Ø OCT

NP		QE			
SENT	RECEIVED	SENT	RECEIVED	SENT	RECEIVED
✗ 645A-Q	✗ 917A-G	✗ 2Ø7A-Q	1	1	1
2	✗ 1Ø12A-G	2	2 11ØA-Q	2	2
3	✗ 1Ø22A-G	3	3	3	3
4 823A-G	✗ 1Ø39A-G	4	4	4	4
✗ 11Ø3A-G	✗ 331-G	5 514A-Q	5 548A-G	5	5
✗ 1232P-G	6	✗ 837A-G	✗ NOON-G	6	6
7	7 1Ø3ØP-X	✗ 855A-G	✗ 1246P-G	7	7
8	✗ 1136P-X	✗ 93ØA-G	✗ 212P-G	8	8
9	9	✗ 3ØØP-G	✗ 7Ø8P-X	9	9
0 445P-6	0 115ØP-X	✗ 733P-X	✗ 715P-X	0	0
✗ 818P-X	1	✗ 1Ø49P-X	✗ 1Ø42P-X	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6 1ØØ6P-X	6	6	6	6	6
✗ 1141P-X	7	7	7	7	7
8	8	8	8	8	8
9	9	9	9	9	9
0	0	0	0	0	0
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6	6	6	6	6	6
7	7	7	7	7	7
8	8	8	8	8	8
9	9	9	9	9	9
0	0	0	0	0	0
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6	6	6	6	6	6
7	7	7	7	7	7
8	8	8	8	8	8
9	9	9	9	9	9
0	0	0	0	0	0
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6	6	6	6	6	6
7	7	7	7	7	7
8	8	8	8	8	8
9	9	9	9	9	9
0	0	0	0	0	0

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FIGURE 14.—Sample of operator's number sheet.

several numbers indicates a group of messages sent in a string. The operator's servicing time for the string is that shown opposite the last number of the series. If it develops that through some oversight one number has been omitted in the numbering of messages to or from a particular station, for example, if five consecutively transmitted messages had carried the numbers 1, 2, 3, 5, 6, respectively, the operator detecting the error enters the notation BLANK, plus his personal sign in the space on the number sheet corresponding to this missing number and notifies the other station concerned to do the same. If two messages are through error assigned the same serial number, the number bearing the latest filing time is assigned the next half number above. For example, if two messages have been given the number 8, the message with the more recent filing time is given the number 8½. The other station concerned is notified to do the same.

84. Traffic check.—At the end of the radio day or just prior to the closing of the net, each station checks traffic with each other station in the net. The use of the procedure sign ZNI facilitates the traffic check. ZNI means: "Prior to closing station records, last message transmitted to you (or to———) was message number———; last message received from you (or from him) was message number ———." The NCS first checks traffic with the secondary station. Using the net call sign, FGG, the NCS (NP) transmits:

FGG V NP ZNI $\overline{\text{XE}}$ MS TWO $\overline{\text{XE}}$ FIVE $\overline{\text{XE}}$ QE ZERO $\overline{\text{XE}}$ ZERO $\overline{\text{XE}}$ RJ SIX $\overline{\text{XE}}$ ZERO $\overline{\text{AR}}$

This indicates that the last message NP has sent to MS is NR2, the last received from MS, NR5; NP has handled no traffic with QE; and his last message sent to RJ was NR6, with none received from RJ. Presuming their records are in agreement, the secondary stations reply:

NP V MS C

NP V QE C

NP V RJ C

If, however, QE's number sheet shows one message received by QE from NP and none transmitted by QE to NP, QE would so state:

NP V QE ZNI ZERO $\overline{\text{XE}}$ ONE $\overline{\text{AR}}$

If, on rechecking, NP observes that this is correct, he transmits to QE:

QE V NP C

Otherwise the two stations make an effort to rectify the error by using any of a series of procedure signals, ZNA to ZNI, provided for this purpose. After the NCS has completed his traffic check with all

secondary stations, the next station in alphabetical or numerical order of call signs will check traffic with the remaining stations, etc., until every station in the net has checked traffic with every other station in the net.

85. Transmissions relating to traffic handling.—*a. Deviations from abbreviated form message procedure.*—Repetitions, verifications, acknowledgments, and other transmissions relating to the signal system are handled in the same manner for normal form messages as for abbreviated form messages with the one principal difference that normal form messages are referred to by serial number (and date if necessary) whereas abbreviated form messages are referred to by station of origin and time of origin. As an example of normal form identification practice consider the verification request:

EF5 V CD3 J NR3 K

This transmission means: "Secure verification of EF5's message number 3 to CD3." The acknowledgment message in answer to the above verification request is a further example:

CD3 V EF5 NR3 GR2 SEVENTH $\overline{\textbf{BT}}$ **NR10 620P K**

In the case of a normal form message which has passed through relay channels and has suffered the accompanying serial number changes, it may be advisable in the interest of clarity to discard the usual normal form identification by number and to refer to the message by station of origin and time of origin (as is done with abbreviated form messages). Thus a message which has reached the addressee through intermediate relays might be followed by an acknowledgment in which the original message is referred to in this abbreviated form manner. Example:

FG V LA NR9 T FR V LA P GR3 THIRTYFIRST
$\overline{\textbf{BT}}$ **FR 341A 400A K**

b. Challenging the check.—When the group count in the heading of a received message is in disagreement with the number of groups in the text as counted by the receiving operator, the receiving operator challenges the check before receipting for the message. Assume that RX has transmitted the following to LC:

LC V RX NR3 D GR 13 TWENTYSEVENTH $\overline{\textbf{BT}}$ **NR15**
WXKZ RNTZ LOPY QRKS TNTU XART NQRK WFTS
RXZY DOGY 620P K

LC copies the message, counts the number of text groups, and finds that the group count should be GR12 instead of GR13. LC transmits:

RX V LC GR12 $\overline{\textbf{IMI}}$ (Isn't GR12 correct?)

RX on recounting finds that LC is correct and replies:

L C V R X C

LC receipts for the message:

R X V L C R

Assume now that RX had properly transmitted GR 12 with the above message but that LC, missing the entire group NQRK in copying, believes the group count to be GR11. LC transmits:

R X V L C GR11 $\overline{\text{IMI}}$

RX, recounting and finding GR12 to be correct, transmits the first letter of each text group as follows:

L C V R X GR12 $\overline{\text{XE}}$ **N W R L Q T X N W R D 6** $\overline{\text{AR}}$

LC readily observes that the second group which begins with N is missing from his copy. Possibly RX failed to transmit this group; possibly LC missed this group in copying. LC requests:

R X V L C $\overline{\text{IMI}}$ **WA X A R T** $\overline{\text{AR}}$

RX complies:

L C V R X X A R T N Q R K $\overline{\text{AR}}$

and LC receipts for the message:

R X V L C R

c. *Long messages.*—Long messages may be broken down into sections of fifty text groups each, the receiving station receipting for each section before the section following is transmitted. Each section except the last is terminated with B ("more to follow") and a number indicating the last group transmitted. For example, CD transmits a long message to EF, in which the fiftieth group is WPLA and the one-hundredth group is UBLA:

E F V C D N R 4 G R 137 TWENTYNINTH $\overline{\text{BT}}$ (49 groups of text) **W P L A B 50 K**

EF either requests repetitions as necessary or receipts for the first fifty groups correctly copied:

C D V E F R 50 K

CD renews transmission with the fifty-first group and continues to the one-hundredth:

E F V C D $\overline{\text{XE}}$ (next 49 groups of the text) **U B L A B 100 K**

EF either requests repetitions again, if necessary, or receipts for the second fifty groups correctly copied, after which CD transmits the remainder of the message, that is, groups 101 through 137.

d. Messages sent in strings.—Normal form messages sent in strings are acknowledged in the following manner:

TW V WG R NR3 TO 10 $\overline{\text{AR}}$

86. Procedure signs and procedure signals.—*a. Procedure signs.*

Procedure sign	*Meaning*
D	Deferred.
P	Priority.

b. Procedure signals.

Classification	Procedure signal	Meaning
N: Numbers	**Z N A**	What was station serial number of last message received from this station (or from ———)?
	Z N B	Station serial number of last message received from you (or from ———) was ———.
	Z N C	What was station serial number of last message you transmitted to me (or to ———)?
	Z N D	Station serial number of last message transmitted to you (or to ———) was ———.
	Z N E	Number ——— from ——— is blank.
	Z N F	Repeat all before group 1 of message number ——— to number ——— transmitted (or transmitted by ———) to straighten out confusion in serial numbers.
	Z N G	Two messages, reference numbers ——— and ——— (or group counts and time of origin ——— and ———), both received as serial number ———. Designate correct serial number.
	Z N H	Change serial number of message with reference numbers ——— ——— (or group count and time of origin ——— ———) to serial number ———.
	Z N I	[1] Prior to closing station records, last message transmitted to you (or to ———) was message number ———; last message from you (or him) was message number ———.

[1] Repeat for as many stations as necessary to complete check.

87. Questions for self-review.—*a.* List the relative advantages of normal form and abbreviated form messages.

b. How would an operator acknowledge receipt of messages NR1, NR2, and NR3 sent in a string?

c. Does a relayed message retain its original station-to-station serial number?

d. Prior to closing stations, the last message which LA has sent to LB is NR2, and the last message which LB has sent to LA is NR8. Show how LA could convey this information to LB, and also how LB could convey this information to LA.

e. A receiving operator counts 23 groups in a message which he has just received. The transmitted heading of the message carries a group count GR22. How does the receiving operator indicate this discrepancy to the transmitting operator? If the transmitting operator on rechecking finds no error in his own group count, what action does he take?

f. How would a message of 212 groups be subdivided for transmission? Show how each subdivision is terminated in transmission.

88. Operation exercise.—*a. Suggestions to instructor.*—(1) Arrange table nets of three stations designating the stations in each net as 6th Corps, 601st Division, and 603d Division. Furnish each operator with—

(*a*) Signal operation instructions in which call signs for these stations may be found.

(*b*) An operator's number sheet.

(*c*) A station log blank.

(*d*) Message forms.

(*e*) Ten "canned" messages in the normal form as they would be furnished the operator by the unit message center. In a few of these messages insert an incorrect group count.

(2) During the actual exercise, deliberate omission of a group in some message and deliberate misnumbering of a message may be directed. This procedure will require practice on the part of the student in correcting such errors.

b. Directions to the student.—(1) Establish the net using call signs found in the signal operation instructions furnished.

(2) Transmit the traffic with which you have been supplied.

(3) Keep a station log and an operator's number sheet.

(4) Check traffic in preparation for closing the net.

(5) Close the net.

Section XI

RADIOTELEPHONE PROCEDURE LESSON I, GENERAL

89. General.—Radiotelephone communication is conducted in a manner similar to that in which radiotelegraph communication is conducted. Thus the radiotelegraph procedure previously presented is used as a background on which instruction in radiotelephone procedure is based. When it is desired to conduct instruction in radiotelephone procedure only, the material covering radiotelegraph procedure for abbreviated form message may be modified easily to adapt it to that purpose. The use of the radiotelephone for signal communication contemplates the transmission of many short messages in the abbreviated form. Rapidity and accuracy of transmission, as well as simplicity of language and procedure, are essential.

90. Phonetic alphabet.—When transmitting individual letters and the component letters of unpronounceable groups by radiotelephone, each letter is spoken as indicated in the phonetic alphabet shown below. This alphabet is habitually used in the transmission of cryptographed texts of messages and of call signs. Thus, group XISV is transmitted as "XRAY INTER SAIL VICTOR," and the call sign GM as "GEORGE MIKE". However, when transmission conditions are favorable and the operators are able to recognize each other's voices without confusion, the use of the phonetic characters for the call signs may be dropped. Under some circumstances, as in artillery air-ground communication, when speed of transmission is important, the entire call-up may be eliminated, once communication has been established. Words, the pronunciation of which is apt to be misunderstood, should be spelled out. Thus BARTS is transmitted

"BARTS, BAKER AFIRM ROGER TARE SAIL" and not "B AS IN BAKER, A FOR AFIRM", etc.

Letter	Spoken as	Letter	Spoken as	Letter	Spoken as
A	AFIRM.	J	JIG.	S	SAIL.
B	BAKER.	K	KING.	T	TARE.
C	CAST. Charlie	L	LOVE.	U	UNIT
D	DOG.	M	MIKE.	V	VICTOR.
E	EASY.	N	NEGAT. Nan	W	WILLIAM.
F	FOX.	O	OPTION.	X	XRAY.
G	GEORGE.	P	PREP.	Y	YOKE.
H	HYPO. How	Q	QUEEN.	Z	ZED.
I [1]	INTER. Item	R	ROGER.		

[1] In joint Army and Navy operations, "I" is "interrogatory."

91. Pronunciation of numerals.—*a*. The following pronunciation of numerals is prescribed for use in all transmissions:

Numeral	Spoken as	Numeral	Spoken as
0	ZE-RO.	5	FI-YIV.
1	WUN.	6	SIKS.
2	TOO.	7	SEV-VEN.
3	THUH-REE.	8	ATE.
4	FO-WER.	9	NI-YEN.

b. Numbers are transmitted by transmitting the separate digits of the number, except in the case of an even hundred, thousand, or million, when the word hundred, thousand, or million is used:

Number:	*Spoken as—*
44	FO-WER FO-WER.
30	THUH-REE ZE-RO.
196	WUN NI-YEN SIKS.
300	THUH-REE HUNDRED.
1572	WUN FI-YIV SEV-VEN TOO.
8000	ATE THOUSAND.
12000	WUN TOO THOUSAND.

92. Procedure signs and procedure signals.—When procedure signs or procedure signals are used in radiotelephone communication,

either procedure words or the exact words in the meanings of procedure signs and procedure signals are spoken. Examples:

Procedure sign or signal:	*Transmitted by radiotelephone as—*
$\overline{\text{AR}}$	ANSWER (applies only when establishing communication).
$\overline{\text{AS}}$	WAIT.
C	THAT IS CORRECT.
E E E E E E E E	ERASE ERASE ERASE.
GR	GROUP COUNT.
$\overline{\text{IX}}$	EXECUTE TO FOLLOW.
$\overline{\text{I X}}$	STAND BY-EXECUTE (in artillery operations, FIRE).
J	VERIFY AND REPEAT.
K	GO AHEAD.
R	ROGER or WILCO (see note below).
T	TRANSMIT or TRANSMIT TO.
V	(in complete call) FROM; (in partial call) THIS IS.
Y	ACKNOWLEDGE.
$\overline{\text{IMI}}$	REPEAT or IS THIS CORRECT?
$\overline{\text{VA}}$	THAT IS ALL (finish of communication).
ZMW	OF WHAT PRECEDENCE AND TO WHOM ARE YOUR MESSAGES?

NOTE.—The word ROGER, which is the phonetic equivalent of the letter R, is used as a general signal of receipt. WILCO, which is a coined word meaning "will carry out orders" or "will comply," is used when the operator receipts for a message which contains an order or a request which he can carry out directly. When an operator handles messages which he gives to his message center, he can properly use only ROGER in receipting for them, regardless of their contents. However, the pilot of an airplane, the commander of a tank or other vehicle, or any commander who uses radiotelephone equipment, is the direct recipient of messages containing orders or requests, and he therefore acknowledges them directly by using WILCO. Of course, if the messages contain information only, and not orders or requests requiring execution, he uses ROGER.

93. Establishing a net.—*a.* UN, LA, and DM are stations in a net having the net call SX. The net is about to go into operation in a tactical situation. The operators are aware of their call signs, of the net frequency, of the time when complete communication within the net is expected, and that UN is the net control station. Under normal circumstances, the net would come into operation as follows:

SAIL XRAY FROM UNIT NEGAT ANSWER

The other stations report in:

UNIT NEGAT FROM DOG MIKE GO AHEAD
UNIT NEGAT FROM LOVE AFIRM GO AHEAD

If all readabilities are satisfactory, it is not necessary to exchange reports, as it is important in all radiotelephone operation to keep net "chatter" down to a minimum. Message traffic can commence

immediately after the net is established in this quick, efficient manner.

b. Suppose that station UN does not make the net call at the prescribed time, possibly because his installation is not yet complete. Station LA is ready, and, hearing nothing on the net frequency, transmits:

SAIL XRAY FROM LOVE AFIRM
STATION REPORTS INTO NET
ANSWER

LA may repeat the call-up as prescribed in radiotelegraph procedure. Station UN, completing his installation and listening on the assigned net frequency, hears LA's transmission and answers:

LOVE AFIRM FROM UNIT NEGAT
READABILITY GOOD
STATION REPORTS INTO NET
NET CONTROL STATION
ANSWER

Since UN gave LA a readability report, his terminating word ANSWER implies, "Give me a readability report." LA answers:

LOVE AFIRM READABILITY GOOD
GO AHEAD

Station UN receipts for this report simply by saying

UNIT NEGAT ROGER

UN then continues to listen on the net frequency for station DM.

c. During the above intercommunication DM, completing his installation and listening on the assigned net frequency, overhears UN and LA working together. He waits for them to complete their transmissions and then transmits:

UNIT NEGAT FROM DOG MIKE
READABILITY GOOD
STATION REPORTS INTO NET
ANSWER

UN replies:

UNIT NEGAT
PERFECTLY READABLE
FOLLOWING STATION IS IN THE NET LOVE AFIRM
NET CONTROL STATION
GO AHEAD

DM complies:

DOG MIKE ROGER

DM now calls LA to exchange readabilities:

LOVE AFIRM FROM DOG MIKE
READABILITY GOOD
ANSWER

LA replies:

LOVE AFIRM
PERFECTLY READABLE
GO AHEAD

DM finishes:

DOG MIKE ROGER

The three stations are now in communication with each other and are ready to exchange traffic.

94. Separate call-ups and answers.—*a*. The use of a separate call-up and answer prior to the transmission of a message, or of operating instructions, is unusual. Only under adverse circumstances of communication are separate call-ups authorized. Thus station JM, having a routine message for station WG, transmits without prior call-up:

WILLIAM GEORGE FROM JIG MIKE
MISSION ACCOMPLISHED
GO AHEAD

b. Under very adverse circumstances of communication, station JM may transmit:

WILLIAM GEORGE FROM JIG MIKE
ANSWER

and, after receiving GO AHEAD from station JM, WG transmits:

WILLIAM GEORGE FROM JIG MIKE
MISSION ACCOMPLISHED
GO AHEAD

Obviously this latter procedure introduces considerable delay and is avoided whenever possible.

95. Receipts and answers.—*a*. Receipts and answers do not contain the call sign of the station which made the transmission being answered. Thus, station WG, in receipting for the message transmitted by JM in paragraph 94*a*, transmits:

WILLIAM GEORGE ROGER

b. Station JM transmits to WG:

WILLIAM GEORGE FROM JIG MIKE
REPORT POSITION
GO AHEAD

If the operator at station WG is both able and authorized (as may be the observer in an airplane) to furnish the required report promptly, he transmits:

WILLIAM GEORGE
FIVE MILES SOUTH OF HARS HYPO
AFIRM ROGER SAIL ON STATE HIGHWAY THREE FOUR
GO AHEAD

and JM receipts:

JIG MIKE ROGER

If the operator at station WG is either unable or unauthorized (as may be the operator at a unit headquarters) to furnish the required report promptly, he acknowledges receipt of the message:

WILLIAM GEORGE ROGER

and transmits a message to station JM as soon as the required information is determined or the answering message is received from proper authority.

96. Repetitions.—A request for a repetition is made by transmitting the word REPEAT after a call. Use of the words GO AHEAD is not required. In replying to a request for a repetition, the entire transmission must be repeated. Thus, if WG failed to receive accurately the transmission from JM shown in paragraph 94*a*, he transmits:

JIG MIKE FROM WILLIAM GEORGE
REPEAT

JM replies:

WILLIAM GEORGE FROM JIG MIKE
MISSION ACCOMPLISHED
GO AHEAD

WG, assuming the message was then correctly received, then transmits:

WILLIAM GEORGE ROGER

97. Closing a net.—The net established as in paragraph 93 is closed by the NCS who transmits:

SAIL XRAY FROM UNIT NEGAT
CLOSE YOUR STATIONS
GO AHEAD

Secondary stations acknowledge in alphabetical order of call signs. Thus DM transmits:

DOG MIKE WILCO

LA then transmits:

LOVE AFIRM WILCO

Note that in this case the operator uses WILCO because he complies directly with the order contained in the message from UN.

98. Difficult communication.—When communication is difficult, receiving stations may request the transmitting station to make transmissions through twice. The transmitting station in complying with such a request transmits the message or other trans-

mission in its entirety and then repeats the entire transmission. Station FG2 makes such a request of station CA by transmitting:

CAST AFIRM FROM FOX GEORGE TWO
MAKE TRANSMISSIONS THROUGH TWICE
GO AHEAD

Station CA complies as follows:

FOX GEORGE TWO FROM CAST AFIRM
REPORT POSITIONS

FOX GEORGE TWO FROM CAST AFIRM
REPORT POSITIONS
GO AHEAD

When the readability of radiotelephone signals is reported as "poor but readable" (ZSB2) the transmitting station automatically makes all transmissions through twice.

99. Questions for self-examination.—*a.* Is there any great difference between radiotelegraph and radiotelephone procedure?

b. The first letter in each word of the phonetic alphabet bears what relationship to the letter which that word represents?

c. How would you transmit the proper name "BREAM", which appeared in the text of a message being transmitted by radiotelephone?

d. How would you transmit the code group "PQTR", in the text of a radiotelephone message?

e. In transmitting procedure signs and signals, is the sign or signal itself transmitted? If not, how is the required information transmitted?

100. Operation exercise, radiotelephone procedure lesson I.—*a. Suggestions for instructor.*—Telephone circuits of three telephones each may be used to represent the radiotelephone net. The telephone at each station is preferably located at such distance from other stations on the same wire circuit as to preclude direct sound transmission from one station to another. Each of the three telephones should be marked as one of the three stations of the net indicated below.

b. Directions to the student.—Your radiotelephone station is represented by the telephone to which you have been assigned. In carrying out the exercises listed in *c* below, speak slowly and distinctly, being careful to enunciate clearly all words and characters that might be misunderstood. Do not shout into the telephone. All readabilities will be indicated as at least 4. Keep a station log. Write therein your own transmissions as well as those of all other stations in the net. Entries on log sheets will be made exactly as spoken except that phonetic alphabet transmissions of call signs may be entered as the

letters involved. Actual operation will be slow. You may find it helpful, particularly during initial stages of the exercise, to write down what you are going to transmit prior to transmitting it.

Organization	Call sign	Frequency
1st DIVISION	CB7 (NCS)	2700 kc.
ADVANCED LANDING FIELD 1st DIVISION.	FB1	
OBSERVATION PLANE IN FLIGHT	KB3 NET CALL—CBB	

c. *Exercise.*—Complete the following requirements in the order given:

(1) NCS will open the net.

(2) FB1 will assume that he heard the transmission of the NCS and will report into the net.

(3) NCS will answer, giving necessary information.

(4) KB3 will assume that he did not hear the transmission of the NCS and FB1 and will report into the net.

(5) NCS will answer KB3.

(6) KB3 will make required transmission.

(7) FB1 will report out of the net temporarily.

(8) NCS will acknowledge.

(9) NCS will ask KB3 if he has anything to transmit.

(10) KB3 will answer, telling NCS he has nothing to transmit.

(11) FB1 will report back into the net.

(12) NCS will answer FB1, transmitting required information.

(13) FB1 will make required transmission.

(14) NCS will order stations closed.

(15) Secondary stations will acknowledge in proper order.

Section XII

RADIOTELEPHONE PROCEDURE LESSON II, MESSAGES

101. Classification of messages.—Messages transmitted by radiotelephone are of the abbreviated form and carry the urgent classification or no classification at all. If a message is classified as urgent, the word URGENT is transmitted in the heading of the message, and the message handled as is the urgent radiotelegraph message of the abbreviated form. (See par. 60.)

102. Omission of $\overline{\text{BT}}$.—Neither the "break" sign $\overline{\text{BT}}$ nor any procedure word corresponding to $\overline{\text{BT}}$ is used in radiotelephone communication. The intonation of the voice is adequate for separating portions of the transmission involved in sending a message.

103. Terminating messages.—Methods of terminating radiotelephone messages are similar to methods of terminating radiotelegraph messages, with the following exceptions:

a. Procedure words are used instead of procedure signs. (See par. 92.)

b. The use of a specific end-of-message sign is less frequent in radiotelephone than in radiotelegraph communication. Intonations of the voice, usually quite apparent in radiotelephone transmission, clearly indicate end of message or transmission. Furthermore, some messages are commands or requests which require no answer. However, when operating conditions are poor and voice intonations are likely to be lost, the use of some formal terminating signal, such as GO AHEAD, THAT IS ALL, etc., is advisable to prevent misunderstandings.

c. The procedure word EXECUTE which replaces the 5-second dash of radiotelegraph communication is used after a call to specify that instructions, orders, or commands contained in the last message will now be carried out. When used at the end of a message it specifies that orders, commands, or instructions contained in the message it terminates will be carried out immediately.

104. Examples of message transmissions.—*a.* Urgent message from JM to WG, receipt for which is required:

WILLIAM GEORGE FROM JIG MIKE
URGENT
ENEMY TANK COLUMN MOVING SOUTH
FROM PREVIOUSLY REPORTED BIVOUAC
GO AHEAD

WG answers:

WILLIAM GEORGE ROGER

b. Routine message transmitted by the "F" method from PL to WG:

WILLIAM GEORGE FROM PREP LOVE
DO NOT ANSWER
ENEMY PLANES RETURNING TO HOSTILE TERRITORY

WILLIAM GEORGE FROM PREP LOVE
DO NOT ANSWER
ENEMY PLANES RETURNING TO HOSTILE TERRITORY
THAT IS ALL

No answer is permitted from WG.

c. Transmission of a routine message to which no answer is desired and in which the context of the message and the intonation of the voice when transmitting it indicate the end of the transmission:

PREP LOVE FROM WILLIAM GEORGE
AM ON MY WAY IN

d. Transmission of an urgent message to which no answer is desired and the context of which is a command which is to be executed immediately:

PREP LOVE FROM WILLIAM GEORGE
URGENT
RETURN TO ADVANCED LANDING FIELD
EXECUTE

105. Relay of messages.—An originator may transmit messages to a receiving station for retransmission to a third station. The procedure words, RELAY TO, replace the procedure sign of radio telegraph procedure for conveying the required retransmission instructions to the relaying station. A receipt from the relaying station may or may not be required. Station WG transmits an urgent message to station JM for relay to station PL, and requests a receipt from station JM in the manner shown below:

JIG MIKE FROM WILLIAM GEORGE
RELAY TO PREP LOVE
URGENT
PROCEED ON MISSION ASSIGNED
GO AHEAD

Station JM answers:

JIG MIKE ROGER

When the above message is transmitted to station PL the call sign of the station of origin followed by the word DIRECTS, REPORTS, or REQUESTS, as the case may be, is placed just preceding the text of the original message, thus:

PREP LOVE FROM JIG MIKE
URGENT
WILLIAM GEORGE DIRECTS PROCEED ON MISSION ASSIGNED
GO AHEAD

Station PL answers:

PREP LOVE ROGER

106. Multiple call.—*a.* The radiotelephone transmission of multiple address messages is accomplished in a manner similar to the transmission of multiple address messages by radiotelegraph, except that the procedure word PLUS is transmitted between the call signs of the called stations.

b. Examples.

JIG MIKE PLUS WILLIAM GEORGE PLUS PREP ROGER FROM TARE WILLIAM RETURN TO AIRDROME ONE IMMEDIATELY AFTER COMPLETION OF ATTACK THAT IS ALL

Note that no answer is required to the above message.

BAKER CAST THREE PLUS FOX GEORGE NINE FROM PREP LOVE FIVE
ENEMY ARTILLERY POSITION ZED ONE
GO AHEAD

Stations BC3 and FG9 answer in the order in which they were called:

BAKER CAST THREE ROGER
FOX GEORGE NINE ROGER

c. If a station fails to answer promptly in its turn, the next station in proper order answers. Stations passed over because of their delay in answering await the completion of answers by other stations before answering.

107. Collective call.—The transmission of a message to several stations simultaneously by means of the collective call is accomplished in a manner comparable to that employed in radiotelegraph messages. Thus a station DM, having a message addressed to all other stations in the same net, the net call of which is SX, transmits:

SAIL XRAY FROM DOG MIKE
REPORT POSITIONS
GO AHEAD

Stations in the net answer in alphabetical or numerical order of call signs as the case may be.

108. Broadcast messages.—Special radio transmitters are frequently employed for the transmission of time signals and press reports. Broadcast messages from such stations are preceded by the general call transmitted three times as follows:

GENERAL CALL ALL STATIONS COPY
GENERAL CALL ALL STATIONS COPY
GENERAL CALL ALL STATIONS COPY

Each transmission is terminated with:

THAT IS ALL

No answer is permitted.

109. Questions for self-review.—*a.* How are radiotelephone messages classified as to precedence in handling?

b. When a receipt of a message is required by a transmitting station, how is that fact indicated to the receiving station?

c. LA, LB, and LC are stations in radio net LFX. Indicate two methods, either of which is suitable for the simultaneous transmission of a message to each of these stations.

d. How do you convey to a receiving station that the message you are about to transmit is to be relayed to a third station?

e. How does a relaying station indicate the station of origin of the message to the station to which he relays the message?

f. Is information received on a general broadcast acknowledged?

110. Operation exercise.—*a. Suggestions for instructor.*—The telephone net described in section XI is employed in carrying out the exercises of this lesson. If the number of students exceeds the number of telephones available, a log and a key operator may be assigned to each station. Messages should be prepared and stations in the same net furnished with different messages. If two operators are assigned to a station, that station's traffic should be divided into two sections. In each section of a station's traffic should be included messages which—

(1) Require an answer.
(2) Require no answer.
(3) Prohibit an answer.
(4) Require a repeat back.
(5) Require a relay to a third station.
(6) Are addressed by a multiple call.
(7) Are addressed by a collective call.
(8) Require the use of the phonetic alphabet in transmitting words likely to be misunderstood.

b. Directions to the student.—Your radiotelephone station is represented by the telephone to which you have been assigned. In carrying out the radiotelephone transmissions listed in *c* below, speak slowly and distinctly, being careful to enunciate clearly. Do not shout into the telephone. Use the phonetic alphabet to spell out words that might be misunderstood. Talking between key and log operators will be held to a minimum. Such conversation as is absolutely necessary will be carried on in a very low voice, as loud talking between key and log operators may be transmitted to the distant stations and

cause considerable confusion. Log operators will keep a complete log. Write down all transmissions from your own and all other stations. Make log entries exactly as spoken by the transmitting operators except that phonetic alphabet transmissions of call signs may be written as the letters represented.

Organization	Call sign	Net call	Frequency
Reconnaissance company, 1st Armored Division.	R C 1	R E C	2700
Advanced command post, 1st Armored Division.	A D 2		
Advanced landing field, 1st Armored Division	A F		

c. Exercise.—(1) Open a free net. No readability will be indicated as less than R4.

(2) Handle first section of your traffic.

(3) Log and key operators change positions and duties.

(4) Handle second section of the traffic.

(5) Close the net.

SECTION XIII

RADIO PROCEDURE IN ARTILLERY NETS

111. General.—*a.* This section covers the radio procedure for the control of field artillery fire, using air observation. The procedure for forward ground observers is essentially the same.

b. The control of artillery fire by radio requires a special procedure designed for brevity, simplicity, and economy of time. Economy of time is particularly essential in the use of airplane observation. Careful prearrangement as to the observer's mission and the method of communication may eliminate much of the routine procedure prescribed in this manual.

112. Codes.—*a.* The Fire-Control Code is used by air and ground observers when fire-control messages are transmitted by radiotelegraph; this facilitates communication for observation and conduct

of fire. The Fire-Control Code is not used in voice transmissions by either wire or radio; however, for uniformity in training radio operators, the clear text equivalent of the code group is used in transmitting fire commands and sensing by radiotelephone.

b. The Air-Ground Liaison Code is used by the Field Artillery primarily for transmitting tactical information. It may be used for the designation of targets for artillery fire control when appropriate code groups do not exist in the Fire-Control Code. *In no case should groups from both codes be mixed in the same message.*

113. Air-ground net.—*a.* The air-ground net of the division artillery includes the division artillery headquarters station (NCS) and the battalion stations. The net is organized on a given frequency (W) as a directed net when a single airplane is present or expected, or on a schedule prescribed by the division artillery headquarters. At all other times the net is silent.

b. Each battalion is assigned a frequency (W, X, Y, Z, or ———) to be used when an airplane is to work only with that battalion. If all units are to use one airplane successively, all stations will work on the frequency (W) or to a designated medium battalion if there is more than one.

c. If more than one airplane is available, each is assigned to a battalion or group of battalions, and a frequency is designated for each airplane These arrangements are made by the division artillery headquarters prior to the take-off of the airplane. Each airplane then reports directly on the prearranged frequency to the battalion or group station that will control its mission. It will be most unusual to require an airplane to change frequency while in flight; if a change in frequency is necessary, ground stations change to the frequency of the airplane.

d. Figure 15 illustrates the organization of a typical division artillery air-ground net.

114. Use of the conventional call-up.—When the air observer has had little work with a particular artillery unit, considerable use of the conventional call-up (e. g., 4CZ V API $\overline{\text{AR}}$) may be necessary initially. However, the break sign $\overline{\text{BT}}$ may be substituted for the entire call-up after communication has been established by radiotelegraph and no interference or difficulty of communication is anticipated. In radiotelephone work the $\overline{\text{BT}}$ is not used (par. 102). The observer merely begins his message without formality.

115. Combating interference.—Hostile radio stations can interfere deliberately with radio communication used in the control of artillery fire, by blocking a single frequency or a band of frequencies,

and by deception, that is, causing friendly stations to accept false or erroneous information, sensings, fire commands, and the like from the enemy. The effects of interference can be minimized by—

a. Training radio operators to work through interference.

b. The strictest observance of radio discipline and radio security.

c. Frequent changes of call signs and frequencies.

d. Limited use of the conventional call-up.

e. Short, quick transmissions.

f. Limiting the number of stations in a net.

g. Careful prearrangement as to methods to be used, and as to the mission of the observer.

h. The use of prearranged signals or groups of letters preceding each transmission to identify the station making the transmission.

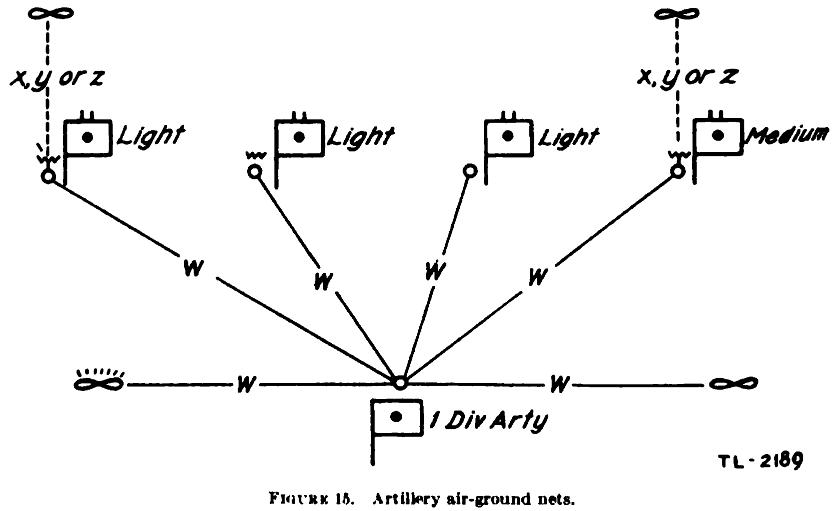

FIGURE 15. Artillery air-ground nets.

116. Illustrative examples.—The examples which follow are given as guides for the training of air observers and radio operators. The Fire-Control Code is used for radiotelegraph transmission; radiotelephone equivalents are also given The conventional call-up, and prearranged transmission for identification, have been omitted.

a. *Example 1*.—(1) *Mission*.—An air observer has the mission of registering, in rapid succession, one battery from each battalion of the division artillery, using centers of impact. The observer is to pin-point the location of each center of impact on an air photo. When these are completed, the air photo is to be dropped at the command post of the division artillery.

(2) *Prearrangement.*—The method is explained to the observer. He is given an air photo of the target area, on which are marked the probable areas of impact. He is informed that, when ready, he is to call for each battery in turn by saying: FIRST BATTERY, FIRE: ——— SECOND BATTERY, FIRE, etc. Each battalion listening in will direct its registering battery to fire at the proper time. The airplane and all battalions are to work on the same frequency. The observer is to check in with the net-control station (division artillery) and then proceed with his mission with no establishment of communication with battalions. The location of the command post, where the photo is to be dropped, is indicated to the observer.

(3) *Communication.*—The observer, having arrived over the position area and having established communication, transmits:

Radiotelegraph	*Radiotelephone*
$\overline{BT}$	
F P	First.
B A	Battery.
$\overline{IX}$ 5-second dash	Fire.
K	Go ahead.

The battalion concerned replies:

R	ROGER.

and, when the battery fires the first round, transmits:

$\overline{BT}$	
2-second dash	Battery fired.
K	Go ahead.

When ready, the observer calls for the next battery:

$\overline{BT}$	
S P	Second.
B A	Battery.
$\overline{IX}$ 5-second dash	Fire.
K	Go ahead.

and the battalion concerned replies:

R	ROGER.

The registration of the other batteries continues as indicated for the first and second batteries. By prearrangement, the reply of the battalion may be omitted, or simple improvised panel signals may be used, since only two are needed.

b. Example 2.—(1) *Mission.*—An air observer has the mission of surveillance of fires for a groupment of three battalions of medium artillery. The groupment [1] is part of the division artillery. The

[1] A groupment is a provisional tactical unit of artillery temporarily formed with two or more artillery battalions.

observer is to report the errors of the initial volleys as quickly as possible in order that any remaining zone fire may be corrected.

(2) *Prearrangement.*—The observer does not check in with the division; he reports directly to the groupment; the three battalions are to listen in on the same frequency. The locations of the position areas and the panel stations are indicated on a photo. The observer understands that panels are to be used in the event of radio silence of ground sets. He is given a gridded photo. On this photo are marked several areas of possible hostile activity. He is to call for fire upon any targets appearing in these areas, or, using the grid for accurate designation, he may call for fire on targets of his own selection in other areas. The fires of one or more battalions may be placed on any target, each battery firing when ready. If more than one battalion is to fire, the observer is to sense on the initial volleys as a whole.

(3) *Communication.*—When the observer sees activity in one of the previously marked areas, he transmits:

$\overline{\text{BT}}$	
CN	Concentration.
52	Five two.
CP	Command post.
SV	Surveillance.
K	Go ahead.

The ground station (groupment) replies:

R	ROGER.

And then sends:

$\overline{\text{BT}}$	
BN	12th Battalion will fire.
12	
$\overline{\text{K}}$	Go ahead.

The 12th Battalion receipts to groupment as follows:

BK7	BK7 (call sign of groupment).
V	From.
AU3	AU3 (call sign of battalion to fire).
R	ROGER.
$\overline{\text{VA}}$	That is all.

This is not only to insure receipt of the groupment's message but also to allow the airplane to tune accurately to the battalion's frequency. Then, as soon as each battery fires, the battalion transmits:

$\overline{\text{BT}}$	
BA	Battery.
A	A (Afirm).
2-second dash	Fired.

B A	Battery.
B	B (Baker).
2-second dash	Fired.
B A	Battery.
C	C (Cast).
2-second dash	Fired.
K	Go ahead.

The observer notes the errors of the three volleys and replies:

$\overline{\text{B T}}$	
B A	Battery.
A	A (Affirm).
30	Three zero.
L L	Left.
50	Five zero.
S S	Short.
B A	Battery.
B	B (Baker).
C R	Range correct.
B A	Battery.
C	C (Cast).
50	Five zero.
OO	Over.
K	Go ahead.

The ground station (battalion) acknowledges:

R	ROGER.

All batteries now correct their zone fire. The observer watches the fire as a whole, and transmits:

$\overline{\text{B T}}$	
R Z	Mission accomplished.
K	Go ahead.

The ground station (groupment) now assumes control and transmits:

$\overline{\text{B T}}$	
R	ROGER.
F I	Follow instructions.
K	Go ahead.

The observer receipts for the message as follows:

$\overline{\text{B T}}$	
R	WILCO.

c. *Example 3.*—(1) *Mission.*—An observer assigned to a battalion of light artillery has the mission of locating targets and adjusting fire upon them.

(2) *Prearrangement.*—The observer does not check in with any intermediate stations. He reports directly to the battalion. Photos and maps are not available; the general locations of the target and position areas are known from a previous reconnaissance flight.

The position area is to be verified by panels. For establishment of scale and orientation and identification of base point, a smoke ladder is to be used.

(3) *Communication.*—The observer, having reported, cannot identify the base point; he transmits:

BT	
MK	Mark.
BP	Base point.
LA	Ladder.
SM	Smoke.
IX 5-second dash	Fire.
K	Go ahead.

The ground station replies:

R	ROGER.

and, when the battery fires, transmits:

BT	
2-second dash	Battery fired.
K	Go ahead.

The observer, after seeing the ladder, acknowledges:

R	ROGER.

and then, after observation of the target area, he discovers infantry forming for a counterattack and sends:

BT	
BP	Base point.
800	Eight hundred.
LL	Left.
200	Two hundred.
SS	Short.
JP	Counterattack.
BN	Request battalion.
AD	Will adjust.
K	Go ahead.

The ground station replies:

R	ROGER.

and as soon as the information is available transmits:

BT	
CN	Concentration.
35	Three five.
BN	Battalion will fire.
A	A (Afirm) battery (Adjusting).
K	Go ahead.

The observer replies:

R	ROGER.

When the battery fires, the ground station transmits:

B T	
2-second dash	Battery fired.
K	Go ahead.

The observer senses and transmits:

B T	
100	One hundred.
R R	Right.
200	Two hundred.
O O	Over.
K	Go ahead.

The ground station replies:

R	ROGER.

The adjustment continues until the observer considers the adjustment sufficiently accurate to request fire for effect. He then transmits:

B T	
20	Two zero.
R R	Right.
C R	Range correct.
F E	Fire for effect.
K	Go ahead.

The ground station replies:

B T	
F E	Will fire for effect.
2-second dash	Battery fired.
K	Go ahead.

and then as each of the other batteries fires:

B T	
B A	Battery.
B (C)	B (Baker) (C) (Cast).
F E	Firing for effect.
K	Go ahead.

The observer may correct the fire of the individual batteries, if this is possible, or correct the massed fire of the battalion as a whole. He may call for fire for effect again, if he believes it necessary, by sending:

B T	
A F	Request additional fire.
F E	Fire for effect.
K	Go ahead.

If the initial fire for effect was sufficient, the observer transmits:

B T	
R Z	Mission accomplished.
K	Go ahead.

If there is no further need for the airplane, the ground station replies:

$\overline{\text{BT}}$	
NF	No further need of you.
K	Go ahead.

or if there are other prearranged missions, the following is transmitted:

$\overline{\text{BT}}$	
CT	Change target.
K	Go ahead.

The observer then looks for the other targets and reports when one is located.

It may be seen that the actual radio operating in artillery fire control communication is very simple, and requires mainly a knowledge of the abbreviated codes that are used for the transmission of information.

117. Questions for self-review.—*a.* Why does artillery fire control by radio require a special procedure?

b. What codes are used in this communication?

c. Is the conventional call-up used in establishing air-ground communication?

d. Under what conditions may the call-up be dropped?

118. Operation exercise.—Suggestions for instructor: If training editions of the Fire-Control Code and the Air-Ground Liaison Code are available, students should be given the opportunity to familiarize themselves with the contents.

APPENDIX I

RADIOTELEGRAPH OPERATOR APTITUDE TEST

U. S. ARMY

SCORE______________

ANSWER SHEET

Directions: Fill in the following concerning yourself.

________________ ________________ ________________ ________________
(Last name) (First name) (Middle initial) (Army serial number)

Grade________________ Organization________________ Age________

Date of present enlistment or Date of induction into service________________ Date today________

Total years service in Army________ Navy________ Marine Corps________

What training and experience have you had in radio operation?________________
____
____
____

How many words per minute can you receive in—

Radio telegraphy (International Morse code)?________________

Wire telegraphy (American Morse code)?________________

Stop here. Put down your pencil and wait for instructions.

PRACTICE ONE

First practice pair. YES NO Third practice pair. YES NO
Second practice pair. YES NO Fourth practice pair. YES NO

1. YES NO	15. YES NO	29. YES NO
2. YES NO	16. YES NO	30. YES NO
3. YES NO	17. YES NO	31. YES NO
4. YES NO	18. YES NO	32. YES NO
5. YES NO	19. YES NO	33. YES NO
6. YES NO	20. YES NO	34. YES NO
7. YES NO	21. YES NO	35. YES NO
8. YES NO	22. YES NO	36. YES NO
9. YES NO	23. YES NO	37. YES NO
10. YES NO	24. YES NO	38. YES NO
11. YES NO	25. YES NO	39. YES NO
12. YES NO	26. YES NO	40. YES NO
13. YES NO	27. YES NO	41. YES NO
14. YES NO	28. YES NO	42. YES NO

43. YES NO	55. YES NO	67. YES NO
44. YES NO	56. YES NO	68. YES NO
45. YES NO	57. YES NO	69. YES NO
46. YES NO	58. YES NO	70. YES NO
47. YES NO	59. YES NO	71. YES NO
48. YES NO	60. YES NO	72. YES NO
49. YES NO	61. YES NO	73. YES NO
50. YES NO	62. YES NO	74. YES NO
51. YES NO	63. YES NO	75. YES NO
52. YES NO	64. YES NO	76. YES NO
53. YES NO	65. YES NO	77. YES NO
54. YES NO	66. YES NO	78. YES NO

INSTRUCTOR'S GUIDE

"Give me your attention."

"This is the Signal Corps Code Aptitude Test. In this test you will hear long and short sounds. This is a short sound (E). This is a series of short sounds (E E E E E). This is a long sound (T). This is a series of long sounds (T T T T T). Here is a group (F). Here is another group (X). When this test starts you will hear two groups of long and short sounds. The groups will be sent in the following order: First group, then a pause; and then the second group. You will indicate on the test paper whether or not the second group sounds exactly like the first. If the second group DOES sound exactly like the first, underline YES. If the second group DOES NOT sound like the first, underline NO. For example: (A A). Those two groups sounded exactly alike; therefore, YES would be underlined if they were sent in the test. Take this example: (G M). Now, those two groups were not exactly alike; therefore, NO would be underlined if they were in the test."

"Take your pencils."

"In the spaces marked PRACTICE ONE, on the first page of the test paper, indicate whether the groups you hear are exactly alike or different."

"Attention!" "First practice pair", (A A). "Those two groups were alike; therefore, you should have underlined the word YES."

"Second practice pair", (F W). "The second group of sounds was different from the first. You should have underlined NO."

"Third practice pair," (Q Q). "Those two groups were alike; therefore, you should have underlined the word YES."

"Fourth practice pair", (V 3). "The second group of sounds was different from the first. You should have underlined the word NO."

"The number of each pair of groups will be called before sending the group. For example: First pair, second pair, and so forth. If you miss a pair go to the next pair when its number is called."

"Turn the page of your test paper."

"First pair" (B 6).
"Second pair" (A U).
"Third pair" (D D).
"Fourth pair" (8 7).
"Fifth pair" (5 5).
"Sixth pair" (1 J).
"Seventh pair" (Z 7).
"Eighth pair" (3 3).
"Ninth pair" (4 V).
"Tenth pair" (L AS).
"Eleventh pair" (Ø MM).
"Twelfth pair" (2 IM).
"Thirteenth pair" (AF UF).
"Fourteenth pair" (BT X).
"Fifteenth pair" (Y Y).
"Sixteenth pair" (KA KR).
"Seventeenth pair" (KN KN).
"Eighteenth pair" (MW NW).
"Nineteenth pair" (KU KU).
"Twentieth pair" (BM BMT).
"Twenty-first pair" (WD WD).
"Twenty-second pair" (KAK KAK).
"Twenty-third pair" (WW WA).
"Twenty-fourth pair" (KL KL).
"Twenty-fifth pair" (KUT KU).
"Twenty-sixth pair" (VS VH).
"Twenty-seventh pair" (BT 6T).
"Twenty-eighth pair" (KM MW).
"Twenty-ninth pair" (MUT MU).
"Thirtieth pair" (WJ WJ).
"Thirty-first pair" (NM NO).
"Thirty-second pair" (KH KS).
"Thirty-third pair" (MI MI).
"Thirty-fourth pair" (KK KX).
"Thirty-fifth pair" (OS M7).
"Thirty-sixth pair" (SN F).
"Thirty-seventh pair" (XK XL).
"Thirty-eighth pair" (XU XU).
"Thirty-ninth pair" (UAD UP).
"Fortieth pair" (6T BT).
"Forty-first pair" (B7 B7).
"Forty-second pair" (WG WG).
"Forty-third pair" (7S 7H).
"Forty-fourth pair" (CV KV).
"Forty-fifth pair" (FL FL).
"Forty-sixth pair" (MP MW).
"Forty-seventh pair" (XZ XD).
"Forty-eighth pair" (B2 D2).
"Forty-ninth pair" (KC KL).
"Fiftieth pair" (PM PM).
"Fifty-first pair" (BLT BLT).
"Fifty-second pair" (YQQ YQZ).
"Fifty-third pair" (RUN RAN).
"Fifty-fourth pair" (BOS BOS).
"Fifty-fifth pair" (KU KA).
"Fifty-sixth pair" (KOI KOI).
"Fifty-seventh pair" (MI MI).
"Fifty-eighth pair" (KXM KBM).
"Fifty-ninth pair" (16 1B).
"Sixtieth pair" (WAA WAR).
"Sixty-first pair" (6X 6X).
"Sixty-second pair" (11 J1).
"Sixty-third pair" (60 60).
"Sixty-fourth pair" (2AS 3AS).
"Sixty-fifth pair" (KM2 KMVM).
"Sixty-sixth pair" (MKR MKL).
"Sixty-seventh pair" (CEY CAY).
"Sixty-eighth pair" (POL PML).
"Sixty-ninth pair" (WAX WAX).
"Seventieth pair" (UNE EAD).
"Seventy-first pair" (MSH MHA).
"Seventy-second pair" (KTD KZ).
"Seventy-third pair" (BCD BCD).
"Seventy-fourth pair" (AUU XU).
"Seventy-fifth pair" (BT3S BT3S).
"Seventy-sixth pair" (VUUI VUUI).
"Seventy-seventh pair" (QQAR QKKR).
"Seventy-eighth pair" (BTOK BTOA).

SOLUTION

1.	YES	NO	27.	YES	NO	53.	YES	NO
2.	YES	NO	28.	YES	NO	54.	YES	NO
3.	YES	NO	29.	YES	NO	55.	YES	NO
4.	YES	NO	30.	YES	NO	56.	YES	NO
5.	YES	NO	31.	YES	NO	57.	YES	NO
6.	YES	NO	32.	YES	NO	58.	YES	NO
7.	YES	NO	33.	YES	NO	59.	YES	NO
8.	YES	NO	34.	YES	NO	60.	YES	NO
9.	YES	NO	35.	YES	NO	61.	YES	NO
10.	YES	NO	36.	YES	NO	62.	YES	NO
11.	YES	NO	37.	YES	NO	63.	YES	NO
12.	YES	NO	38.	YES	NO	64.	YES	NO
13.	YES	NO	39.	YES	NO	65.	YES	NO
14.	YES	NO	40.	YES	NO	66.	YES	NO
15.	YES	NO	41.	YES	NO	67.	YES	NO
16.	YES	NO	42.	YES	NO	68.	YES	NO
17.	YES	NO	43.	YES	NO	69.	YES	NO
18.	YES	NO	44.	YES	NO	70.	YES	NO
19.	YES	NO	45.	YES	NO	71.	YES	NO
20.	YES	NO	46.	YES	NO	72.	YES	NO
21.	YES	NO	47.	YES	NO	73.	YES	NO
22.	YES	NO	48.	YES	NO	74.	YES	NO
23.	YES	NO	49.	YES	NO	75.	YES	NO
24.	YES	NO	50.	YES	NO	76.	YES	NO
25.	YES	NO	51.	YES	NO	77.	YES	NO
26.	YES	NO	52.	YES	NO	78.	YES	NO

APPENDIX II

PRACTICE GROUPS AND MESSAGES *

PART I

Code groups

Exercise 1.—5 words per minute

O V L H	M Y B L	U R X O	H I Z O	V I C T
F I N X	X C S H	X T Y V	I Q N T	U B M L

Exercise 2.—5 words per minute

A B L B	E J L N	C Y Z B	Z W C N	J N D Z
U T Z L	K L A B	D E F Z	V N U W	K F R E

Exercise 3.—5 words per minute

J I C O Y	T X S T Y	3 8 7 Ø 1	R D I H A	J X T D Z
O X P D W	X P Z S Y	R S P H D	8 9 7 6 Ø	C U S P I

Exercise 4.—5 words per minute

R N B R J	6 5 2 8 9	Z O N I G	F Y E Q U	A R Q N V
S N L P T	K A K O Z	8 8 2 1 7	B V G A N	W K O Q T

Exercise 5.—5 words per minute

S R Q M T	U J V W N	4 6 5 2 1	Y X G C X	A F K O Z
C D E H K	N I H G P	1 2 3 2 7	Z W Q M N	B H L Y C

*NOTES

1. Exercises 1 to 56, inclusive, furnish material for 2 minutes of sending at speeds of 5, 7, 10, 15, and 20 code groups per minute.
2. Exercises 57 to 60, inclusive, furnish clear text material, to be sent at any desired speed. Number of words per line and total number of words in exercise are indicated.
3. Exercises 61 to 85, inclusive, furnish traffic handled in field radio nets. This traffic may be transmitted at any desired speed.

442750°—42——7

Exercise 6.—5 words per minute

O G L C T	8 Ø 9 4 2	X H N L F	K H G X S	B Z V R E
L D F G H	S I Q Y O	A R J F X	8 3 9 Ø 5	U D L O M

Exercise 7.—5 words per minute

O L M X	M V N H	U W Q R	N V U T	K U X F
C D E H	L Y H E	D I P A	Z Q W I	A Y S K

Exercise 8.—5 words per minute

Q I Q A	W M N W	Z I H Z	C A K D	B T G W
W N L I	P W B U	O X A D	X F R J	I Q C A

Exercise 9.—5 words per minute

Z M J Z I	U R Y N C	9 3 8 2 7	P Q A Z M	D E G V M
N C B V G	H U G H Y	1 3 2 6 7	M D N I E	F W X E T

Exercise 10.—5 words per minute

1 2 8 9 Ø	M C N D H	E U I R Y	W Q Z X S	I R S V Z
M C U R I	7 2 4 3 9	O Q N Z I	P I Q A W	C N J W O

Exercise 11.—5 words per minute

O W Q A J	O I S K M	1 Ø 7 6 Ø	D G F H G	K S B O U
W E X C Z	D Y R I U	Q A U Z N	4 7 1 6 9	J H F N Q

Exercise 12.—5 words per minute

5 8 7 2 1	L D G U A	D K H P K	U K E O L	C R T N V
K E O X J	C K N C T	A E B C L	3 4 6 4 8	Q L M I A

Exercise 13.—7 words per minute

U T H A	V N C B	R F D S	E D C D	C Z V D	D S F D	U Y H G
R W Q I	L M N J	T N B L	U J H K	S H G N	C A N C	4 3 7 1

Exercise 14.—7 words per minute

N I O Q	J U Y R	G B N S	V C X T	R J T U	Y H G V	V N C W
B C D V	U T H N	A U Y R	U T N G	U Y T R	V B H F	5 1 4 8

Exercise 15.—7 words per minute

R U Y E	C G F H	5 7 8 1	J H V X	R E B V	H U G T	Z A Q K
E F R T	I U R L	D X I Z	U I T K	H G J D	Q A I W	N B V C

Exercise 16.—7 words per minute

K J H B	O P L J	V R C E	U B H Y	N V B C	1 5 3 4	E R D V
J U T N	G R L D	Q U D C	V H I G	Q C A Y	Z A S F	A C B D

Exercise 17.—7 words per minute

B U R L I	T X O E C	A X Z I L	U N G B T	V X N H B	1 7 4 5 5	T O N O M
W S Q D E	O I C J N	F L F F L	H Z A C D	T K N O Z	K C L P H	B C D B C

Exercise 18.—7 words per minute

T U L C C	J W N A W	R S V N U	K Z Q G E	I J L O T	A I Y U G	G O T X H
S H R N J	Ø 5 6 9 4	N B Z T F	H A S Y I	N Q M E V	T V G I O	W S D M R

Exercise 19.—7 words per minute

I B R Z J	O Z L F W	1 9 Ø 4 3	X T N C S	D K W R D	J C Q A K	P H K G X
E L V Q C	K D P H L	Q G J H Y	V X E L Q	F M U P B	L E C C M	R F I A Z

Exercise 20.—7 words per minute

A F W Y F	W Z R S T	S U N K N	O P C Y L	K K F E Q	B E X Z B	4 7 3 7 2
T T L O R	P Q D A K	L J E F R	C D Y A D	T B P P R	U S M S U	Q R I T J

Exercise 21.—7 words per minute

D C Z C E	Z E O M N	V H N V Z	R D J B I	N H L H T	1 9 1 4 9	E X T R L
B X N L R	Y Z E N C	U Y I N F	Y H B V G	B E I J N	V B H G N	A D V K O

Exercise 22.—7 words per minute

A H Q X B	B U I M Y	N C S T O	Q D S T Z	H E X L M	F Y M B U	G J R C J
O N T R O	R U O W A	A P V K L	W Z N X C	K Y A D K	A W L O W	P E D G N

Exercise 23.—7 words per minute

S K E U B	Z P B J K	O C O Y D	I Z Y H L	B X K P B	Q F O F M	T L V C C
T D P Z E	F I M P I	C Y J Q U	R G B H L	U M V S D	X R Z H I	U E Q A F

Exercise 24.—7 words per minute

G N O Q J	D Z I R T	S H A S R	V N X T E	W X Y G H	V F R U G	8 Ø 3 2 1
T D I U R	K O B D Z	A K U X E	F P S Q D	A W H B T	D L T Y E	O P R V R

Exercise 25.—7 words per minute

I E R U T	G H F N J	V T U F Y	D J U G H	S N K A D	9 8 7 3 1	Q W A D S
U J H D S	C U T Y R	A G H S D	F E H J H	I J K S L	M N H N Y	U T Y G H

Exercise 26.—7 words per minute

V N X A X	D B G H B	T Y G N H	Q W E R T	5 4 4 Ø	O P I K J	N B V J S
W N F S A	J B I N Y	J I C O Y	T X S T Y	R D A I H	O X P D W	X P Z S Y

Exercise 27.—7 words per minute

I B R Z J	O X L F W	1 Ø 9 4 3	X T N C S	D K W D R	J C Q A D	P H K G X
I L V Q C	K D P B L	Q G J H Q	V X E L Q	F M U P B	L E C C M	P F I A Z

Exercise 28.—7 words per minute

A F W Y F	W Z R S T	S U K N O	O P C L Y	D K F E Q	B E X Z B	4 7 3 7 2
T T L O R	P Q D A K	L J E F R	C Y D A D	Y B P P R	U S M S U	Q R I G J

Exercise 29.—10 words per minute

S O L V	C M Y B	C U R S	P Z Y W	B F I N	G X C C	H O L Q	P I Q N	A J L N	S K B A
T W P I	B K S A	F T U Q	O U S Y	C S J P	D Y T D	E K M P	F J R O	I Z P Y	T Q U R

Exercise 30.— 10 words per minute

NBLB AEJL WCYZ ZWNJ TUTZ DKLA CDEF AVNU NCZA KAJL
ABVS MEKC MANL HSNU TUSC NWZA WNFS JBIN VRPE NZHR

Exercise 31.—10 words per minute

JICOY TXSTY 387Ø1 RDIHA OXPDW XPZSY PSPHD 89464 CWVPF HIQLE
LWQOX HNGEW OVOCN RNQIZ XEYPQ PVDER 9Ø675 PVRTM MNATU QBIYO

Exercise 32.— 10 words per minute

RNBRJ 62589 ZONIG FYEQU SNLPT KAKOQ 88217 BVGAN DNVOB QEXGI
HNEXE DROTC TMLQC BNPCU HIMAN FDWCS UNMPO YTIOB TDXEN CWCRN

Exercise 33.—10 words per minute

SRQMT UJVWN WNJKD YXGGX CEDHI NIHCP 12327 ZWQMN OYNKR BULTY
UBPXF VDMBO 1Ø974 DHINK QZJME PCSHN TGWIN BXALY AACUC RRHIL

Exercise 34.—10 words per minute

OGLCT 8Ø942 XHNLF HKGXS LDGHF SIQUO ARJFX AUBWP KCLFN XTYER
DIDNW 36541 NEURY NHGDA LENVX ZQIRU IEOLD 839Ø3 TUULB DCINE

Exercise 35.— 10 words per minute

OLMS MVNH UWQR CDEH KDNQ DIPA QZWI MCCX MCCX OSJJ
ZLUN LDKM BCNX ZYZU GHJD OSLP NCMY DFJU DJFU NAJS

Exercise 36.— 10 words per minute

IQAO MNWX IJZA QWZE NLID WBUA PXOI FJRA ZAPQ JRGD
YQUA USJN NZXC SJAN EYRU LAMZ EURY MKOP AGTX DAQY

Exercise 37.—10 words per minute

ZMJZI URYCH 93287 PQAZM NCBVG HUGHY DIEUR MDNIE OSSME ERRRT
27394 MCUEH KALZX COPLC UEYRY OSIKJ OIDSJ OIDKS MEUYR CUTZO

Exercise 38.—10 words per minute

1289Ø	MCNHD	EIURY	WZQXS	MCURI	KDJND	OQNZI	QPIAW	OXNDK	MCTTL
MNAGH	Ø1876	LCMNX	KSIEU	UQTZX	72439	MCNBX	OIEZX	UIETC	SGVBD

Exercise 39.—10 words per minute

SWQAJ	OISKM	1Ø76Ø	DFHJG	WEXCZ	DYRIU	QUAMN	IRNVB	MLIFN	BCFMF
RQPSM	47196	TUJVM	XYZAC	VBUWX	YXTLD	PONIM	ILKUT	QUAZR	PCLKD

Exercise 40.—10 words per minute

57921	LDGUA	DKHPK	UKEOL	KEOSJ	CKNCT	AEBCK	GOJVW	ABRVT	LHIJZ
39ØØ6	MNIHN	FRKDJ	SJHVF	CBMFR	INIFM	EIMGQ	1Ø7Ø1	MCUNK	KCUTY

Exercise 41.—15 words per minute

IUTH	BVNC	ERFD	WEDC	XCZV	SDSD	IUYH	EWRQ	ILUJ	DSHG
XCAN	ABDH	KLLO	YTNB	HNIO	MJRY	HGBS	BVCX	IUJH	IRJT
YYHG	HVNC	BBCD	IUTH	QAUY	HUNT	JURY	NNVH	VNRG	VNCX

Exercise 42.—15 words per minute

RUYE	CGHF	TDCN	JHVH	REBV	HUGT	ZAQK	ERFI	TURL	DIZX
UITK	HGJD	QAIW	NBVC	EJFN	KJHB	OPLJ	VRCE	UBHY	NVCB
OIDG	ERDV	JUTN	GRLD	QUDC	VHIG	QCAY	ZASF	ABCD	BNBH

Exercise 43.—15 words per minute

BURLI	TXOEC	AXZIL	UNGBT	VXNBH	17455	TONOM	WSQDE	OIGJN	FLFFL
BCDBC	BZACD	TKNOZ	KCLPX	NOTED	TULCC	JWNAW	RSVNU	KZQGE	KJLOT
AIYUG	GOTXH	SRJHN	Ø4594	NBZTF	HASYI	NQMEV	TVGIO	WSDMR	CJASE

Exercise 44.—15 words per minute

IBRZJ	OZLFW	19Ø43	XTCNS	DKWRD	JAQAK	PHKGX	ELVQC	KDBLI	QGHUY
VXELQ	FMUPB	LECCM	RFIAZ	YBOUT	AFWFY	WZRST	SUKNO	OPYCL	KKFEQ
BEZXB	47372	TTLOR	PQDAK	LJEFR	CDYAD	YBPPR	USMSU	QRITJ	KIKGS

Exercise 45.—15 words per minute

DCZC	ZEMO	VHNV	NHLH	ENTZ	EXTR	BXNL	YZEC	RDJB	UYIN
YHBV	BEIJ	VBJG	ADVK	PASV	AHQX	BUIM	NCST	QDST	HEXI
FYMB	GJRC	ONTR	ROUW	APVK	WZNX	KYAD	AWOL	PEGD	OAKW

Exercise 46.—15 words per minute

SKEUB	ZPBJK	OCOYD	IZYHL	BXKPV	TLVCC	TDPZE	FIMPI	AFOFM	CYJQU
RGLBH	UMVSD	XRZHI	UEZAF	Ø5647	GNOQJ	DZIRT	SHASR	VNSTE	WSYGH
VFRUG	8Ø321	TDIRU	KOBDZ	AKUKE	FPSQD	AWBHT	DLTYE	OPRVR	DXFIN

Exercise 47.—15 words per minute

IERUT	GHFNJ	VTUFY	DJUGH	SNKAD	89731	QWADS	JUSWE	UJHDS	CUTYR
AHGSB	FHEJH	IJKSL	MIJNY	UTYGH	VNZXZ	DHFGB	UTGNH	QWERT	5443Ø
OPHIJ	NVBJS	CFCVF	WNFSA	JBINY	JICOY	TXSTY	RDIAH	OXDPW	XPZSY

Exercise 48.—15 words per minute

IBRJZ	OZLFW	1Ø943	XTCNS	DKWRD	JCQAK	PIKGX	UWFKP	ELVAC	KDPBL
QGJKQ	VXELQ	FMUPB	LECCM	PFIAX	AFWYF	WZRST	SUKNO	OPCYL	KKEFQ
TTLOR	BEXZB	47372	XAQOZ	PDQAK	LJEFR	CYDAD	YBPPR	USMSU	QRITJ

Exercise 49.—20 words per minute

ZAYU	YRSB	NYHL	HBSZ	NQYN	SFBL	TSXA	NYAV	OCTG	HMTU
WUGT	ORLO	UVSK	XILR	UWVL	YPOM	JIVA	VWJK	DESL	TWXI
VXBF	UAWN	YRAV	TXYS	CXNZ	OCAR	MRZN	BLSR	KMOY	IOTL
JUMN	VWAX	ADKH	EBCL	VBBC	WUDG	JCTE	KYIS	PDNA	SLHZ

Exercise 50.—20 words per minute

TRSA	WVNT	XURU	SVYN	WXZT	TYZL	MCGW	DLDA	DCDF	AVNU
TGPE	MCKC	MXKL	HNBU	JWZA	TUXZ	WNFS	JNIN	JICO	YHQI
SPHD	QXOC	ZGEW	MOBT	VUOA	RNQI	XEYP	PDDF	PVRT	RNBR
XLTC	PRAW	ZOUO	FYEQ	SNLH	HAOK	BVGO	PGUN	PRQA	ZOUL

Exercise 51.—20 words per minute

HENEX DRTOT TCQML UPBCN NMHIA 42597 JUMOM BZCND DTQUI RHEYU
MCNVT TMLCQ BCNUP HIMAN 97425 JUMOM DTORT UEYRH NCBZC QIIDT
MCNZA QXQCZ KNNZU PQLIK WEIRY ZNXAB OQUWU Ø89Ø1 PQZIL ERUDT
KDMSM MCIUJ KDJLO 92837 QVBAF XVZQS OKSAI LOAJN 21968 ZUISH

Exercise 52.—20 words per minute

GHNFI OSIAW ZXNCE IREUH JSNHF BNDNX JSNFH OEIUR 8765Ø PQAKH
MCNBX IEURY NYDHE Ø1298 KDJMZ XJIAQ MZBAQ BKIVM YDRTE MJKER
PSLAQ FRTJF 3982Ø PDLSK AMNZB ZVZGG ANXYU TSTDI ASHIE FGPWN
9Ø347 HAVGO WVRUR CVBTJ DFGOH LIBPF Ø9638 HICPOV QDWCG DSIEN

Exercise 53.—20 words per minute

OKICQ CEMID 972Ø1 ALCRJ MAIDP JRNOL 2468Ø JXEFY EFXNK DLZIK
76321 EWSKM CTOG EFMEY LCKQH PHVTX 7Ø365 HZGNA AXBTR 49285
OCYAA HIMAD OHWIM SFMCG Ø3759 JNABD ZLJBI CPNZI VTNEE FMEMI
CWXCK JBCYD 847Ø7 JBOAH JELKF ZDLYS DKAKX PGZUN DKDNG GYEVZ

Exercise 54.—20 words per minute

47382 KTLES WQYFZ CTILL FHFUX ARJZU MRFXE WBPCM OMIWG THQVI
NTVMG DXAQN 4Ø367 SPEJN HSPCQ HMOUS WOHZR 119Ø2 OBRDK VIODO
XGLDT TVCPT IPAZQ Ø6143 PVFKQ CUBEZ 8Ø7Ø1 CPTKO FNZQJ CPTKO
RBEFP AXTRX RKMOZ 2Ø184 PGMAE IRAGO KDIEY KCNYQ EKJCD VNFBH

Exercise 55.—20 words per minute

1Ø273 PZOKA MDIDH EIURY DJHNG DIEUY DXNZE OQUIW Ø9165 MCNBS
HAHGJ JCUWH 98234 MCNUY QZASU IHDJI LDOSJ 83746 JEHDY BCNBX
CVFZA SCQZW 1231Ø LKDOP MCNCB ZAOIZ ZLKAM ZJHFG BAYQT WEQFQ
PAOKU 3Ø21Ø JDMNF DKEUR QNBAV 17868 MDNHA TQRYW EIOUW MXNBG

Exercise 56.—20 words per minute

25894	MVHVD	UEYTA	ZMNZB	ZXVGX	OIEUI	JXHGQ	APLKM	QYEUR	NDBGY
UYRHI	LKCCN	98Ø15	NDHBH	QWZXN	KDIOE	DYAFH	LPWCA	MBUDF	JTIOE
MNOPA	CVQAR	12754	OEVAN	AEIOU	MNLFG	KQZAX	NASTF	PONDL	FAWZX
13579	YOUMK	LARDO	CFGIL	NPQRT	QWERT	CJRNO	VOIUM	MQECV	CADXA

PART II

Clear text

Exercise 57

EVERY ACTION IS A WISE OR UNWISE INVESTMENT FOR FUTURE	(10)
DIVIDENDS THE PAST IS GONE WHAT WE CALL THE PRESENT MOMENT	(11)
GOES OVER TO THE PAST EVEN WHILE WE ARE SAYING THE WORD LEAVING	(13)
ONLY THE FUTURE IN WHICH TO WORK AND ENJOY WHATEVER WE DO IS	(13)
DONE FOR AN EFFECT IN THAT FUTURE BE IT NEAR OR FAR A MINUTE	(14)
OR A YEAR CONSIDER WELL THEN THE EFFECT YOU ARE TRYING TO	(12)
PRODUCE	(1)
Total words	(74)

Exercise 58

THE LOCAL INTERESTS OF A STATE OUGHT IN EVERY CASE	(10)
TO GIVE WAY TO THE INTERESTS OF THE UNION FOR WHEN A SACRIFICE	(13)
OF ONE OR THE OTHER IS NECESSARY THE FORMER BECOMES ONLY AN	(12)
APPARENT PARTIAL INTEREST AND SHOULD YIELD ON THE PRINCIPLE	(9)
THAT THE SMALL GOOD OUGHT NEVER TO OPPOSE THE GREAT ONE WHEN	(12)
YOU ASSEMBLE FROM YOUR SEVERAL COUNTRIES IN THE LEGISLATURE	(9)
WERE EVERY MEMBER TO BE GUIDED ONLY BY THE APPARENT INTERESTS	(11)
OF HIS COUNTRY GOVERNMENT WOULD BE IMPRACTICABLE	(7)
Total words	(83)

Exercise 59

THESE ARE THE TIMES THAT TRY MENS SOULS THE SUMMER	(10)
SOLDIER AND THE SUNSHINE PATRIOT WILL IN THIS CRISIS SHRINK	(10)
FROM THE SERVICE OF THEIR COUNTRY BUT HE THAT STANDS IT NOW	(12)
DESERVES THE LOVE AND THANKS OF MAN AND WOMAN TYRANNY LIKE	(11)
HELL IS NOT EASILY CONQUERED YET WE HAVE THIS CONSOLATION	(10)
WITH US THAT THE HARDER THE CONFLICT THE MORE GLORIOUS THE	(11)
TRIUMPH WHAT WE OBTAIN TOO CHEAPLY WE ESTEEM TOO LIGHTLY IT	(11)
IS DEARNESS ONLY THAT GIVES EVERYTHING ITS VALUE	(8)
Total words	(83)

Exercise 60

IT IS REFRESHING TO KNOW THAT THERE ARE GREAT FORCES	(10)
FOR GOOD AT WORK IN THE BUSINESS WORLD THAT IMPROVEMENTS ARE	(11)
BUT THE NATURAL EXPRESSION OF UPLIFTED THOUGHT THAT EXAMPLE	(9)
PURER MOTIVES HIGHER IDEALS AND THE RIVALRY OF EXCELLENCE	(9)
ARE LEAVING THE WORLD THAT OPPRESSION IS DECREASING IN ORDER	(10)
THAT SPONTANEOUS EFFORT MAY BE UTILIZED THAT COURTESY AND	(9)
KINDNESS ARE GAINING RECOGNITION AS FACTORS OF SUCCESS AND	(9)
THAT MEN ARE LEARNING TO LOVE THEIR DAILY WORK BECAUSE THROUGH	(11)
IT THEY FEEL THE DIVINE IMPULSE	(6)
Total words	(84)

PART III

Tactical net traffic

Exercise 61

OG 3 V MY 9 Y O $\overline{BT}$
NR 3 CD OMEYA TANDG FOEVY NICEL PABEX TALFO MISHQ YEDHG
XILVM COQWK DAVZO VASOL UTINY FWEAJ OVIXA YASUL GAGGJ FOLXY
921A K

Exercise 62

OG 3 V MY 9 $\overline{BT}$
NR 7 CD DAFOL CYOZN QOSID GALNU FIFTK JNMZE DALDD FOYEV
CALKU ZOZYG MAKSV SONIZ SMEAG KAKTU VASTB 937A K

Exercise 63

OG 3 V MY 9 G $\overline{BT}$
NR 15 CD AMISD COXEN GAILO VEAND BOVER TAFTE SIZXE MASIO
QASSU VIONT GAFYS LOXIL JEYSI SIMAR DETTE IPREC DIFSO CALGU
PRSOZ 939A K

Exercise 64

OG 3 V MY 9 T LB 7 V MY 9 O $\overline{BT}$
NR 6 CONCENTRATION OF ENEMY FORCE INDICATES MAIN EFFORT AGAINST HILL TWO SIXTY 943A K

Exercise 65

OG 3 V MY 9 F Y $\overline{BT}$
NR 4 CD PASQX MHIOJ YUSET KALKE SASSY VARIV BLEDT HCADJ
UXELY PEQJN SISMT HISVK LESIS QIFEJ VEWID FORMC VEWID TRUCA
DAQIN UYVAL NUNBC BOEPD SALRF DAUSE BAUYI FQICE 947A $\overline{VA}$

Exercise 66

OG 3 V MY 9 $\overline{BT}$
NR 8 DUMPS ESTABLISHED AS AGREED UPON AND READY FOR FIRST TRAIN 952A K

Exercise 67

OG 3V	MY 9G	$\overline{BT}$							
NR 1 1	DFCT 1	HIHO	DANY	MASU	SAPV	IUNA	HAVR	SISO	XABJ
MAME	QUEL	VADE	JAJI	MISH	CALU	VIXO	PAOY	GETX	VWEN
SUZH	KLWE	PEIN	TATU	ENXY	LEFG	955A	K		

Exercise 68

OG 3 V	MY 9 T	XU 2 V	MY 9 Y	$\overline{BT}$					
CD	GOXDR	FADUL	KIJEY	NAMIH	LAEDG	PRYNO	CAJIN	ZEDBL	DOFIN
AWENJ	957A	K							

Exercise 69

OG 3 V MY 9 $\overline{BT}$

PILOT OF ENEMY PLANE CAPTURED AND BEING HELD PENDING ARRIVAL OF INTERPRETER 957A K

Exercise 70

OG 3 V	MY 9 G	$\overline{BT}$							
DFCT 1	HOLW	VISK	SUMC	LXPN	COBA	PYSN	ZJEL	HEVX	WUCA
FIST	BEUJ	KWDL	SXIM	KHEN	FIFO	DYXA	JEVO	YIRZ	XYOL
AJEN	BAGL	JISY	958A	K					

Exercise 71

OG 3 V MY 9 F BT

NR 2 3 SCOUTS REPORT ENEMY CONCENTRATIONS IN VICINITY OF BISCHENWEILER WITH SEVERAL TANKS ADVANCING ALONG KALDFARM ROAD TEN PM 1ØØ3A $\overline{VA}$

Exercise 72

OG 3 V	MY 9 $\overline{BT}$								
CD	KEWBA	LIHJU	NEIDG	SAVOL	KRYST	ALMUN	ZODEV	SASIF	DUNYX
FUCEN	DELIO	1ØØ7A	K						

Exercise 73

OG 3 V MY 9 $\overline{BT}$

NR 1 4 THREE PRISONERS CAPTURED BY FIRST BN EARLY THIS MORNING RELIABLY REPORT COUNTER SAPPING WORKS ARE BEING DRIVEN IN POSITIONS IN ADVANCE OF EAGLEROCK 1Ø12A K

Exercise 74

OG3 V MY9 O $\overline{BT}$
NR15 CD BAVOV CEALD PYSNO TARIX OLIVA DESMR XELDM ZAZKH
MYSED TAIOZ MEMNO DAFUG LIGNO GEYKZ 1Ø13A K

Exercise 75

OG3 V MY9 NR15 GR26 TWENTYFIVE $\overline{BT}$
NR11 DFCT1 JELD KOSI RUVA BEBY NULZ FOSH JELJ USEN
HIHO DEKY ESEN PYSK CELB JEYQ QUAD NEPT RUGX LILQ
DEFM KIHE VOWJ MEDK YEKH 1Ø14A K

Exercise 76

OG3 V MY9 NR16 GR1Ø TWENTYFIVE $\overline{BT}$
NR76 CD NUGWH WIGSO ZLAYS APDWT ZOTQB ITBQW RLUMN 8ØØP K

Exercise 77

OG3 V MY9 NR17Y O GR3Ø TWENTYFIVE $\overline{BT}$
NR12 REPLACEMENTS CAN DETOUR ROUTE AT CROSSING SIX FORTY TWO ACCOUNT HEAVY SHELL FIRE STOP IN NO CASE TO ARRIVE BEFORE DARK AS OUR APPROACH SYSTEM IS UNDER OBSERVATION 1Ø17A K

Exercise 78

OG3 V MY9 NR18 P GR18 TWENTYFIVE $\overline{BT}$
NR21 CD SIVAN DAMIX PYSEG ADFUB LEKGA LILEB DAZEJ TEPIX
CEDIJ KHEMI YEVAK CMENQ HYXFJ ULSHO PXENY 1Ø19A K

Exercise 79

OG3 V MY9 NR19 P G GR19 TWENTYFIVE $\overline{BT}$
URGENTLY REQUIRE REPLACEMENT FOR ONE STORAGE BATTERY TYPE BB EIGHTEEN FOR TRUCK TWO THREE SEVEN ONE EIGHT THREE 1Ø17A K

Exercise 80

OG3 V MY9 NR2Ø F GR24 TWENTYFIVE $\overline{\text{BT}}$
NR23 DFCT1 SESA JIYC NOHV DELC FIMQ WING JELK VEXY
DALT CEJV RAKY VOLX CENG YIBW SEMU COLD STYX DEMI
OLIN YENY 1Ø2ØA $\overline{\text{VA}}$

Exercise 81

OG3 V MY9 NR21 G GR15 TWENTYFIVE $\overline{\text{BT}}$
NR 22 OUR CASUALTY LISTS DELAYED BY ERROR OF MESSENGER BUT WILL ARRIVE BEFORE MIDNIGHT
1Ø28A K

Exercise 82

OG3 V MY 9 NR 22 O GR 24 TWENTYFIVE $\overline{\text{BT}}$
CD OMIXT DEFSU YALMO LTRDI CALKE VOSIN FULIC ERSTY KOSIL
BELDO TAMUC WALIG SASMY REQIN ZONDE DENCE YEYOC PRUNY VOXEJ
CAMEK HOBUX SEVYX 1Ø29A K

Exercise 83

OG3 V MY9 NR23 NITE GR22 TWENTYFIVE $\overline{\text{BT}}$
NR29 SPOT AMMUNITION AS REQUESTED BY LAKELAND THIS MORNING STOP OUR MEN WILL BE ON HAND
TO RECEIVE IT AT ZEBANDEN 1Ø33A K

Exercise 84

OG3 V MY9 NR24 O Y GR21 TWENTYFIVE $\overline{\text{BT}}$
NR23 DFCT1 JONI PADE VEXT YUZP VEWS CAJG SELB DOFI
MESK JULY KLUC ROTE PALU DIXT PEYG RUGA DEPN SADE
1Ø29A K

Exercise 85

OG3 V MY9 NR25 F P GR13 TWENTYFIVE $\overline{\text{BT}}$
REPORT ARRIVAL OF MAJOR RINELAND BY TELEPHONE UPON ARRIVAL
YOUR CP 1Ø25A $\overline{\text{VA}}$

APPENDIX III

PROCEDURE SIGNS AND SIGNALS

PROCEDURE SIGNS

	Sign	*Meaning*
$\overline{\text{A A}}$	• — • —	Unknown station. Blank.
A A	• — • —	All after.
A B	• — — • • •	All before.
$\overline{\text{A R}}$	• — • — •	End of transmission.
$\overline{\text{A S}}$	• — • • •	Wait.
B	— • • •	More to follow.
$\overline{\text{B T}}$	— • • • —	Break.
C	— • — •	Affirmative. Correct.
D	— • •	Deferred.
D U P E	— • • • • — • — — • •	Duplicate message.
E E E E E E E E	• • • • • • • •	Error. Erase.
F	• • — •	Do not transmit. Do not answer.
G	— — •	Repeat back.
G R	— — • • — •	Group(s).
$\overline{\text{I M I}}$	• • — — • •	Repeat. Question mark.
$\overline{\text{I X}}$	• • — • • —	Execute to follow.
$\overline{\text{I X}}$ (5 second dash)	• • — • • ————	Execute.
J	• — — —	Verify and repeat.
K	— • —	Go ahead. (Transmit.)
L	• — • •	General relay.
N	— •	Not received. Negative. Exempted.
N R	— • • — •	Number.
O	— — —	Urgent.
P	• — — •	Priority.
Q	— — • —	Information.
R	• — •	Receipt. Routine.
S	• • •	Signal strength.
T	—	Transmit (to).
V	• • • —	From. Calling.
$\overline{\text{V A}}$	• • • — • —	Finish.
W	• — —	Interference.
W A	• — — • —	Word after.
$\overline{\text{X E}}$	— • • — •	Slant (/) or separator.
Y	— • — —	Acknowledge.
Z	— — • •	Originator.
U[1]	• • —	Net control station.
$\overline{\text{H M}}$[2]	• • • • — —	Silence.
$\overline{\text{U O}}$[2]	• • — — — —	Negative silence.

[1] Used by Army with identical meaning of ZGD.
[2] Employed by Army for net control purposes.

Procedure Signals

(A) ANSWERING—AIRCRAFT—AUTHENTICATION

Z A A You are causing delay by slowness in answering.
Z A B You are causing confusion by answering out of order.
Z A C Answer in alphabetical order of call signs.
Z A D Answer me (or ———) on ——— kc.
Z A E Am reeling in antenna ——— (1. Before landing; 2. To rejoin formation).
Z A F Am forced to land (at or near ———) because of ——— (1. Fire; 2. Collision; 3. Engine failure; 4. Out of gas).
Z A G --
Z A H --
Z A I --
Z A J --
Z A K --
Z A L --

* * * * * * *

Z A R Check your message authentication.
Z A S Message authentication has been checked and is ———. (1. Correct; 2. Incorrect, corrected authentication is ———).
Z A T --
Z A U --
Z A V --
Z A W --
Z A X --
Z A Y --
Z A Z --

(B) CALL SIGNS

Z B A --
Z B B --
Z B C --
Z B D --
Z B E --
Z B F --
Z B G --
Z B H --
Z B I --

* * * * * * *

Z B S --
Z B T --
Z B U --
Z B V --
Z B W --
Z B X --
Z B Y --
Z B Z --

(C) CALLING—COMMUNICATIONS

ZCA Are you (or is ———) in communication with ——— (by ———) (1. Radio; 2. Wire; 3. Visual)?
ZCB I am (or ——— is) in communication with ——— (by ———) (1. Radio; 2. Wire; 3. Visual).
ZCC Call me again at ——— (on ——— kc.).
ZCD Following is what I (or ———) sent (at ———).
ZCE I have (or ——— has) been calling you (on ——— kc.).
ZCF I (or ———) will call you again as soon as I (he) can (or at ———) (on ——— kc.).
ZCG Inform ——— that I have (or ——— has) been calling him (on ——— kc.).
ZCH Cease listening for messages from ———.
ZCI Listen in for messages from ——— (on ——— kc.).
ZCJ You were (or ——— was) sending at the same time as ———.
ZCK Transmit message(s) without preliminary call-up.
ZCL Make (or direct ——— to make) preliminary call-up before transmitting traffic.
ZCM Collective (or net) call sign ——— for the present includes ———.
ZCN --
ZCO --
ZCP --

* * * * * * *

ZCV General call; all stations copy.
ZCW --
ZCX --
ZCY --
ZCZ --

(D) DIRECTION FINDER

ZDA Transmit "MO's" and call signs (on ——— kc.).
ZDB Report bearings by direction finder in plain English.
ZDC What is my bearing (code understood if not followed by ZDB)?
ZDD Your bearing in code was ——— at ———.
ZDE Your bearing in plain English was ——— at ———.
ZDF Your bearing from ——— was ——— (and distance from ——— was ———) at ———.
ZDG Bearing furnished you is ——— (1. Bilateral; 2. Unilateral).
ZDH I am unable to furnish you (or ———) bearing now. Call again in ——— minutes.
ZDI I am (or ——— is) now ready to furnish you (or ———) with radio direction-finder bearings.
ZDJ I am (or ——— is) unable to furnish reliable bearings due to (1. Night effect; 2. Poor minimum; 3. Uncalibrated sector; 4. Weak signals; 5. Poor note; 6. Interference; 7. Uncalibrated frequency; 8. Poor cross).
ZDK What is my bearing and distance from you (or ———)?
ZDL What is reciprocal of bearing just furnished me by you (or ———)?

ZDM	Reciprocal of bearing just furnished you by me (or ———) is ———.
ZDN	Bearings appear to be reliable.
ZDO	--
ZDP	--
ZDQ	--
ZDR	--

* * * * * * *

ZDV	--
ZDW	--
ZDX	--
ZDY	--
ZDZ	--

(E) EQUIPMENT, ADJUSTMENTS OF EQUIPMENT

ZEA	I am (or ——— is) going to use ———.
ZEB	Use ———.
ZEC	I am (or ——— is) unable to use ———.
ZED	My ——— (on ——— kc.) is out of commission.
ZEE	Repairs completed. Am in commission now.
ZEF	I have adjusted my ——— (1. Radiating system; 2. Power).
ZEG	Cease using ———.
ZEH	I am (or ——— is) using ———.
ZEI	Your ——— appears to be defective (on ——— kc.).
ZEJ	Your key or relay appears to be sticking.
ZEK	Your speed key is improperly adjusted.
ZEL	--
ZEM	--
ZEN	--
ZEO	--
ZEP	--
ZEQ	How is my note?
ZER	Your note is ——— (1. Good; 2. Poor; 3. Rising and falling; 4. Over-modulated; 5. Under-modulated).
ZES	Your dots are ——— (1. Too heavy; 2. Too light).
ZET	Your (or ———) transmitter is not keying properly.
ZEU	--
ZEV	--
ZEW	--
ZEX	--
ZEY	--
ZEZ	--

(F) FREQUENCY, FREQUENCY ADJUSTMENTS

ZFA	I must shift to work another station (or ———).
ZFB	Frequency ——— mc.
ZFC	Frequency ——— kc.
ZFD	Send V's on this frequency (or ——— kc.).
ZFE	I am (or ——— is) shifting to transmit on ——— kc. (at ———).
ZFF	I am (or ——— is) shifting to receive on ——— kc. (at ———).
ZFG	I am (or ——— is) able to receive on ——— kc.

ZFH I am (or ——— is) able to transmit on ——— kc.
ZFI Shift (or direct ———) to receive on ——— kc.
ZFJ Shift (or direct ———) to transmit on ——— kc.
ZFK Shift (or direct ———) to transmit and receive on ——— kc.
ZFL What frequency are you (or is ———) using (to work ———)?
ZFM How does my frequency check?
ZFN Your frequency is correct.
ZFO Your frequency is too high (or is ——— kc. too high).
ZFP Your frequency is too low (or is ——— kc. too low).
ZFQ Your frequency is ——— kc.
ZFR Adjust your transmitter frequency to zero beat with mine (or with ———).

* * * * * * *

ZFW --
ZFX --
ZFY --
ZFZ --

(G) NET CONTROL (ARMY), GUARDS (NAVY)

ZGA Indicate ships or stations for which you are radio guard (net control station) (——— kc.).
ZGB Take over radio guard or net control for ——— (until ———).
ZGC Are you (or is ———) radio guard or net control station for ——— (on ——— kc.).
ZGD I am (or ——— is) radio guard or net control station for ——— (on ——— kc.).
ZGE --
ZGF --
ZGG --
ZGH --
ZGI --

* * * * * * *

ZGL --
ZGM --
ZGN --
ZGO --
ZGP --
ZGQ Station reports into net.
ZGR Station leaves net temporarily (or for ——— hours) (to communicate with ———) (will be on ——— kc.).
ZGS Is net directed or free?
ZGT Net is ——— (1. Directed; 2. Free).
ZGU --
ZGV --
ZGW --
ZGX --
ZGY --
ZGZ --

(L) LIST OF TYPES AND MEANS OF COMMUNICATION

ZLA CW ----------
ZLB ICW ----------
ZLC Type or model ——— transmitter.
ZLD Type or model ——— receiver.
ZLE Landline or cable ——— (1. Telegraph; 2. Telephone).
ZLF Visual.
ZLG Radio ——— (1. Radio beacon; 2. Aircraft radio; 3. Field radio; 4. Radiotelegraph; 5. Radiotelephone; 6. Direction finder).
ZLH ----------
ZLI ----------
ZLJ ----------
ZLK ----------
ZLL ----------

* * * * * * *

ZLP ----------

* * * * * * *

ZLS ----------
ZLT ----------
ZLU ----------
ZLV ----------
ZLW ----------
ZLX ----------
ZLY ----------
ZLZ ----------

(M) MESSAGES, TRAFFIC

ZMA I have (or ——— has) ——— messages (numeral indicating number of messages may be followed by O, P, or D to indicate precedence other than routine) for you (or ———).
ZMB Nothing received from ——— (at ———).
ZMC Fragments only received (from ———).
ZMD Have you received SOS just made (or made by ——— at ———)?
ZME The following is heading of message ——— as received. Check station of origin if necessary and repeat.
ZMF Unable to locate message(s) ———. Give better identification data.
ZMG This message is in error— disregard it.
ZMH How do you count following text group(s) ——— ———? Word (or words ——— ———) should be counted as ——— group(s).
ZMI Hold my message number ——— until correctness is confirmed.
ZMJ Following received from ——— (at ———).
ZMK Verify enciphering (or encoding) of your message ——— (or portion indicated).
ZML Cryptographic system indicated in your message ——— (1. Is not held; 2. Is inoperative).
ZMM ----------

* * * * * * *

ZMV ----------
ZMW Of what precedence and to whom are your messages?

ZMX Verify the message or portion thereof indicated with your message center (communication office) and transmit correct version.
ZMY --
ZMZ --

(N) STATION SERIAL NUMBERS

ZNA What was station serial number of last message received from this station (or from ———)?
ZNB Station serial number of last message received from you (or from ———) was ———.
ZNC What was station serial number of last message you transmitted to me (or to ———)?
ZND Station serial number of last message transmitted to you (or to ———) was ———.
ZNE Number ——— from ——— is blank.
ZNF Repeat all before group 1 of message number ——— to number ——— transmitted (or trasmitted by ———) to straighten out confusion in serial numbers.
ZNG Two messages, reference numbers ——— and ——— (or group counts and time of origin ——— and ———), both received as serial number ———. Designate correct serial number.
ZNH Change serial number of message with reference numbers ——— ——— (or group count and time of origin ——— ———) to serial number ———.
ZNI Prior to closing station records, last message transmitted to you (or to ———) was message number ———; last message received from you (or him) was message number ———.
NOTE.—Repeat for as many stations as necessary to complete check.
ZNJ --
ZNK --
ZNL --
ZNM --
ZNN --

* * * * * * *

ZNS --
ZNT --
ZNU --
ZNV --
ZNW --
ZNX --
ZNY --
ZNZ --

(O) OPERATING

ZOA Send at speed of ——— words per minute.
ZOB Your ——— (1. Characters are indistinct; 2. Words are poorly spaced; 3. Transmitter or key missing dots).
ZOC Has executive sign (signal of execution) for last message (or for message following ———) been made?

ZOD Transmit your messages in strings of ———.
ZOE I am going to transmit my messages in strings of ———.
ZOF Cease using speed key.
ZOG --
ZOH --
ZOI --
ZOJ --
ZOK --
ZOL --
ZOM Use speed key if qualified to do so.

* * * * * * *

ZOT --
ZOU --
ZOV --
ZOW --
ZOX --
ZOY --
ZOZ --

(P) FACSIMILE (JOINT); OPERATING (NAVY)

ZPA --
ZPB --
ZPC --
ZPD --
ZPE --

* * * * * * *

ZPU --
ZPV --
ZPW --
ZPX --
ZPY --
ZPZ --

(R) RETRANSMISSION, ROUTING, RELAYING, AND DELIVERY

ZRA Forward this message (or message ———) by visual to ———.
ZRB Deliver (or direct ——— deliver) message(s) ——— via ——— (to ———).
ZRC Act as relay between me (or ———) and ———.
ZRD Give me your message(s) for ———; I will forward.
ZRE Forward this message by wire ——— (1. Collect; 2. Paid).
ZRF Take no further action with regard to forwarding message ——— (to ———).
ZRG Transmit this message now (or at ———) by ——— (1. I method; 2. F method).
ZRH Inform me when this message (or message ———) has been received by addressee(s) (or by ———).
ZRI Message ——— has been received by the addressee (or by ———) at ———.

ZRJ Pass following message to destination by ——— (1. Hand; 2. U. S. Postal Service; 3. Fast mail).
ZRK Distribute this message by dispatch where no charges are involved and to all others by mail.
ZRL How route traffic for ———?
ZRM Route traffic for ——— through ——— (on ——— kc.).
ZRN Have been unable to relay (or deliver) message ——— to ——— (1. Will continue efforts to effect relay (or delivery); 2. Advise disposition).

* * * * * * *

ZRP --

* * * * * * *

ZRZ --

(S) SIGNALS, SIGNAL STRENGTH, READABILITY

ZSA Can you receive ———? If so, what is his readability?
ZSB I can receive ———. Readability ———.
ZSC Your signals fade (from strength ——— to ———).
ZSD Decrease strength of signals.
ZSE Increase strength of signals.
ZSF What is my signal strength?
ZSG What is my readability?
ZSH --
ZSI --
ZSJ --
ZSK --
ZSL --
ZSM --
ZSN --
ZSO Reception ——— (1. Poor; 2. Fair; 3. Good; 4. Excellent; 5. Impossible; 6. Impossible due to echo).
ZSP --
ZSQ --
ZSR --
ZSS --
ZST --
ZSU --
ZSV --
ZSW --
ZSX --
ZSY --
ZSZ --

(T) TIME AND TRANSMISSIONS

ZTA I am (or ——— is) going to make a timing signal for correcting clocks. The numerals indicating the time (and zone ——— plus or minus understood) will be followed by the executive sign—the 5-second dash terminating exactly at the time indicated.
ZTB What is your time and time zone?
ZTC My time is ——— zone ——— time (plus or minus understood).
ZTD From ——— to ———.
ZTE Until further orders (or until ———).
ZTF Established at ——— (by ———).

ZTG At ———.
ZTH Did you (or ———) transmit anything for me? If so, please repeat.
ZTI Trasmit traffic blind (or broadcast traffic) to me (or to ——— on ——— kc.). I (or ———) will receipt for traffic later (on ——— kc.).
ZTJ Transmit only urgent or priority messages.
ZTK Routine messages may be transmitted now.
ZTL --
ZTM --
ZTN --
ZTO --
ZTP --

* * * * * * *

ZTT --
ZTU --
ZTV --
ZTW --
ZTX --
ZTY --
ZTZ --

(V) MISCELLANEOUS AIRCRAFT

ZVA --
ZVB --
ZVC --
ZVD --
ZVE --
ZVF --
ZVG --
ZVH --
ZVI --
ZVJ --

* * * * * * *

ZVS --
ZVT --
ZVU --
ZVV --
ZVW --
ZVX --
ZVY --
ZVZ --

(W) WATCHES AND SCHEDULES

ZWA Close or secure (or direct ——— to close or secure) your (his) station or watch (on ——— kc.).
ZWB Are you (or is ———) maintaining continuous watch on ——— kc.?
ZWC I am (or ——— is) maintaining a continuous watch on ——— kc.
ZWD Request (or ——— requests) permission to secure watch (or close station) on ——— kc.
ZWE I am (or ——— is) securing watch (or closing station) on ——— kc.
ZWF What stations are keeping watch on ——— kc. (or are in net)?

ZWG Following stations are keeping watch on ——— kc (or are in net).
ZWH ----------
ZWI ----------
ZWJ ----------
ZWK ----------

* * * * * * *

ZWV ----------
ZWW ----------
ZWX ----------
ZWY ----------
ZWZ ----------

(X) AUTOMATICS

ZXA ----------
ZXB ----------
ZXC ----------
ZXD ----------

* * * * * * *

ZXG Use hand key.

* * * * * * *

ZXI ----------

* * * * * * *

ZXS ----------
ZXT ----------
ZXU ----------

ZXV ----------
ZXW ----------
ZXX ----------
ZXY ----------
ZXZ ----------

(Y) TEMPORARY SIGNALS

For Navy and Coast Guard Use

ZYA ----------
ZYB ----------
ZYC ----------
ZYD ----------
ZYE ----------
ZYF ----------
ZYG ----------
ZYH ----------
ZYI ----------
ZYJ ----------
ZYK ----------
ZYL ----------
ZYM ----------
ZYN ----------
ZYO ----------
ZYP ----------

SIGNAL CORPS

For Army Use Only

ZYQ ....

ZYR ....

ZYS ....

ZYT ....

ZYU ....

ZYV ....

ZYW ....

ZYX ....

ZYY ....

ZYZ ....

(Z) MISCELLANEOUS

ZZA Stand by.

ZZB Negative, no, not.

ZZC Affirmative, yes.

ZZD Meaning of your (or ———'s) procedure signal (or procedure sign) is not understood.

ZZE ....

ZZF ....

ZZG ....

ZZH ....

ZZI ....

ZZJ ....

* * * * * * *

ZZM ....

* * * * * * *

ZZU ....

ZZV ....

ZZW ....

ZZX ....

ZZY ....

ZZZ ....

APPENDIX IV

THE INTERNATIONAL MORSE CODE

A	.—	M	——	Y	—.——
B	—...	N	—.	Z	——..
C	—.—.	O	———	1	.————
D	—..	P	.——.	2	..———
E	.	Q	——.—	3	...——
F	..—.	R	.—.	4	....—
G	——.	S	...	5	.....
H	....	T	—	6	—....
I	..	U	..—	7	——...
J	.———	V	...—	8	———..
K	—.—	W	.——	9	————.
L	.—..	X	—..—	Ø	—————

SPECIAL CHARACTERS

Period (.) .—.—.—
Comma (,) ——..——
Colon (:) ———...
Interrogation (?) or request to repeat ..——..
Apostrophe (') .————.
Hyphen or dash(—) —....—
Wait .—...
Fraction bar (/) —..—.
Brackets or parentheses ( ) —.——.—
Starting signal —.—.—
Underline (__) ..——.—
Double dash (=) —...—
Understood ...—.
Error ....
Cross or end (+) .—.—.
Invitation to transmit —.—
End of work ...—.—
Separation between whole number and fraction .—..—
Is it correct ..—.—

INDEX

INDEX

[A. G. 062.11 (2-24-42).]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:
J. A. ULIO,
Major General,
The Adjutant General.

DISTRIBUTION:
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(For explanation of symbols see FM 21-6.)

U. S. GOVERNMENT PRINTING OFFICE: 1942

TM 11-455

WAR DEPARTMENT

TECHNICAL MANUAL

RADIO FUNDAMENTALS

July 17, 1941

TECHNICAL MANUAL No. 11-455 } WAR DEPARTMENT, WASHINGTON, July 17, 1941.

RADIO FUNDAMENTALS

Prepared under direction of the
Chief Signal Officer

SECTION I

GENERAL

1. Introduction.—The basic laws which govern electrical phenomena in radio communication systems are the same as in power systems. A discussion of these basic principles of electricity is presented in TM 1-455, and it is presumed that the student is acquainted with the material contained therein. TM 1-455 includes a study of

the current and voltage relations in elementary direct current (d. c.) and alternating current (a. c.) circuits with applications to power equipment and to measuring instruments. This manual presents a discussion of applications of these basic principles to radio transmitters and receivers. A knowledge of the fundamentals of radio enables a radio operator or radio technician to understand the equipment he handles and to obtain the best results in its employment.

2. Communication frequencies.—Communication frequencies are divided generally into two broad groups, audio frequencies and radio frequencies.

a. Audio frequencies are those between, roughly, 20 and 15,000 cycles per second. Sound waves with frequencies in this range are those to which the human ear normally responds. Sounds which occur at frequencies below 20 cycles per second, such as the staccato tappings of a woodpecker, are recognizable more as individual impulses than as tones. The frequencies that are most important in rendering human speech intelligible fall approximately between 200 and 2,500 cycles per second; that is, vibrations per second. The fundamental range of a pipe organ is from about 16 to 5,000 cycles, and the highest fundamental note of the flute is about 4,000 cycles. Speech and music actually consist of very complicated combinations of vibration frequencies of irregular and changing shape; harmonics, or overtones, which are multiples of the fundamental tones, give individual characteristics to sounds of the same fundamental frequency from different sources. It has been determined by experiment that the human ear responds best to sounds of about 2,000 cycles. Sound waves around 15,000 cycles per second, such as those due to very high pitched whistles, are likely to be inaudible to the average ear.

b. Frequencies from, roughly, 50 kilocycles per second to 500 megacycles per second are referred to as radio frequencies. These are the frequencies employed in the propagation of radio waves. Frequencies below 500 kilocycles (per second) are employed for some army and marine services; frequencies between 500 and 1,500 kilocycles are used for standard broadcasting; and frequencies above 1,500 kilocycles are used for many types of operation, including amateur, police, general commercial, and army radio communication.

3. Distributed inductance and capacitance.—*a.* In addition to the inductance and capacitance included in inductors and capacitors, there are distributed, or stray, inductance and capacitance effects present in miscellaneous components of radio instruments, as in connecting wires, switches, and sockets. These become of considerable concern at radio frequencies.

b. Capacitive reactance is inversely proportional to the frequency $\left(X_C=\frac{1}{2\pi fC}\right)$. This means that as the frequency of an applied voltage is increased, the capacitance of the circuit offers less opposition to the flow of current, so that at high frequencies undesirably large currents may appear where negligible currents would flow at low frequencies. The inherent capacitance which occurs between adjacent elements of a vacuum tube or between adjacent turns of a coil presents a large capacitive reactance at the lower frequencies. However, at radio frequencies the reactance may become sufficiently small that the increased magnitude of the current flowing across it determines the upper frequency limit for the usefulness of the associated circuit.

c. Inductive reactance increases proportionally to frequency $(X_L=2\pi fL)$, which means that as the frequency of an applied voltage is increased, the inductance of the circuit offers more opposition to the flow of current. A simple connecting wire, the inductive reactance of which may be insignificant at low frequencies, may have a sufficiently large inductive reactance at higher frequencies to render an instrument inoperative.

4. Effective a. c. resistance.—Fundamentally, a measure of the resistance of a circuit is given by the power dissipated as heat when unit current is flowing in the circuit. In its broadest sense, the term "resistance" is taken to mean all effects leading to a dissipation of energy in any form such that the energy is not recoverable for any useful purpose within the immediate system. Thus a radio antenna for transmitting is said to have a radiation resistance associated with radiative "losses," that is, with the energy which is radiated into space; and a particular transmitter or receiver circuit may be said to exhibit certain "reflected" resistance because of the power consumed by other circuits which it directly or indirectly supplies. With alternating current, for a given current magnitude, considerably more electrical power may be consumed than is required by the same circuit with direct current. The resistance which is indicated by a. c. power consumption is called "effective" a. c. resistance. Part of this additional power is required to maintain the heat losses accompanying parasitic circulating currents (eddy currents) which are induced in conductors of the circuit (in particular, in transformer cores) by the varying magnetic field. Another source of a. c. electrical power dissipation is represented by dielectric and hysteresis losses. In the presence of an electric field a dielectric polarizes, that is, the constituent atoms of the dielectric are alined in the direction of the field, being reversed as the

field reverses. With rapidly changing fields such as are encountered in radio, the energy expended during the polarization is often appreciable. This energy appears as heat and is not recoverable in useful form, so it constitutes a definite loss. A similar effect that occurs in a magnetic material which finds itself in a varying magnetic field, for example in transformer cores, is referred to as hysteresis loss. A further factor which makes for more required power for a given magnitude alternating current is the "skin effect," the tendency of alternating currents to travel with greater density near the surface of the conductor than at the center. This tendency increases with frequency. The magnetic field about a current-carrying conductor is more intense at the center of the conductor than it is near the surface of the conductor. Thus the back voltage set up by the rising and falling magnetic field (Lenz's Law) is greater at the center than near the surface, and practically all of the current through a wire at high frequencies is confined to the outer surface of the conductor. The result is increased heating for the same current, that is, higher resistance. The nonuniform distribution of current throughout the cross section of a conductor at high frequencies is more pronounced if the conductor is wound into the form of a coil than it is if it is used as a straight wire. At radio frequencies the effective a. c. resistance of a coil may be 10 or 100 times its true d. c. resistance. Wherever alternating cirrents are studied, it is generally understood, if not specifically stated, that "resistance" means effective a. c. resistance.

5. Insulators.—Insulators which are satisfactory for power purposes may not be suitable for radio work. In radio circuits which operate with microwatts of energy, dielectric losses, which appear, for example, in the dielectric bars which insulate the stator plates from the frame of a variable air capacitor, are of definite concern. Also of interest are the minute leakage currents on insulator surfaces, for example, tube bases and sockets. It is well to keep radio insulators away from strong electric fields, and to maintain all insulators dry and clean.

SECTION II

RESONANT CIRCUITS

6. Vector representation of voltage and current.—*a*. The simplest type of recurrent voltage or current is a sine wave type, that is, one whose instantaneous magnitude may be graphically represented as varying with time in accordance with the sine curve of figure 1. A current or voltage varying in exactly this manner is rarely, if ever,

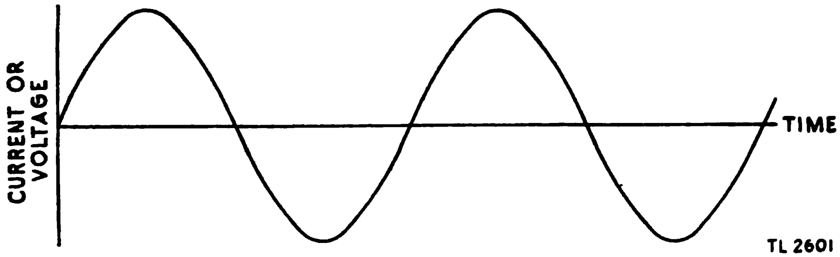


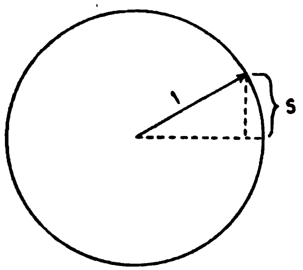
FIGURE 1.—Sine current or voltage.

attained in practice. However, the sine wave is a convenient simplification for analysis, and its use in this connection is justified by the fact that any regularly recurrent voltage or current may be regarded as a composite of individual sine waves. For all purposes of circuit analysis only sine wave currents and voltages will be considered, the actual resultant effect in any case being a composite of the individual effects so considered. (See TM 1-455.)

b. To facilitate representation, a sine curve such as that of figure 1 may be indicated as in figure 2 by an arrow of unit length which rotates at a uniform rate. The vertical projection, *S*, of the arrow represents instantaneous magnitude of the sine action. Consider that the arrow begins rotation when it is pointing horizontally to the right (figure 3①). After it has rotated 30° the arrow is at *B*, and the vertical projection is at *B′* as shown in figure 3②. Rotating another 30° brings the arrow to *C* and the projection to *C′*. A complete rotation of the arrow is accompanied by the corresponding curve traced

out by the projection as shown in figure 3③. Continuous rotation produces the repeated sine wave of figure 3④.

c. Had the arrow started rotating when it was pointing up, figure 3⑤, that is, 90° ahead of its former starting position, the accompany-



TL-2602

Figure 2.—Uniformly rotating vector. Projection *S* develops a sine action.

ing sine curve would have appeared as in figure 3⑥. The sine curves of ⑥ and of ③ differ in phase by 90°; the former is said to be "leading" the latter by 90°, the latter "lagging" the former by 90°.

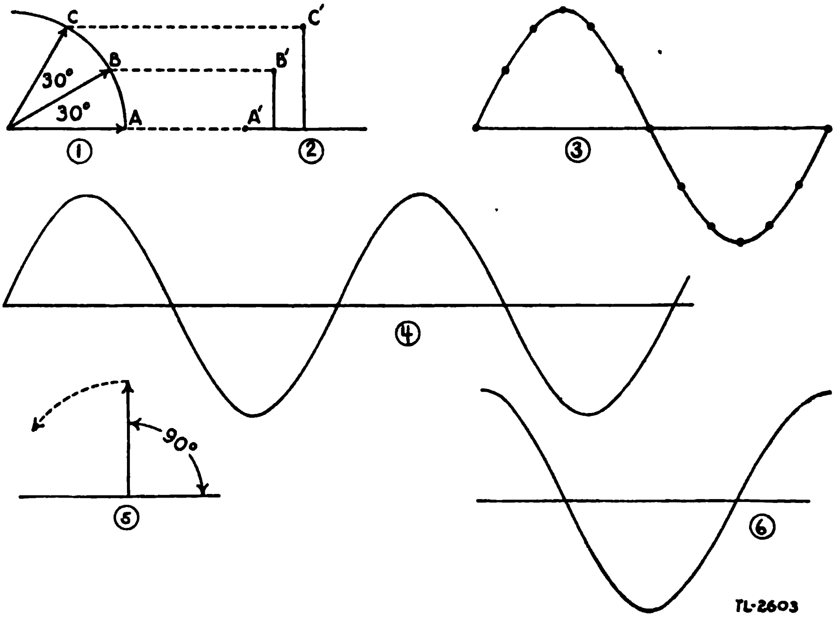


Figure 3.—Development of sine curves.

The curves of ⑥ and of ③ might represent sine waves of current of the same amplitude and frequency which differ in phase by 90°.

Or, if the curve of ③ is taken to represent the wave of alternating voltage across a capacitor, ⑥ may be employed to represent the wave of (leading) current. More simply, the current and voltage could be represented by their corresponding vectors, *i* and *e* of figure 4①. The vectors are "photographs" of the rotating arrows at any particular instant. The particular instant represented by figure 4① is that at the beginning of the rotation. Figure 4② shows the same arrows a quarter cycle later. Either the sine curve or the vector representation presents an adequate picture of the phase relationship

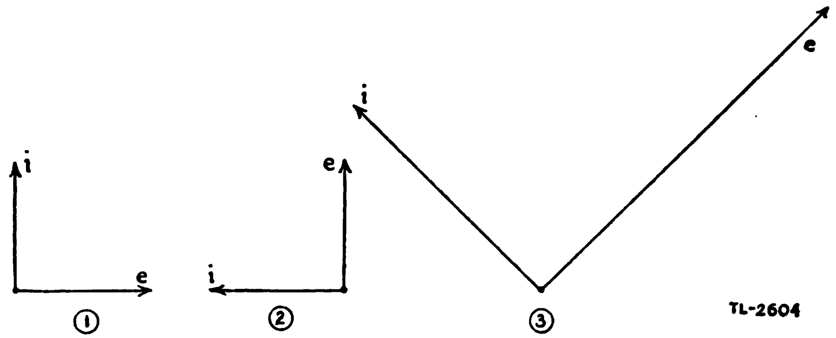


FIGURE 4.—Vector representation of currents and voltages.

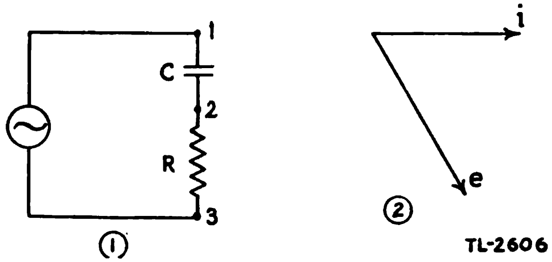
between the current and voltage. In a vector picture the magnitudes of the current and the voltage are indicated by the relative lengths of the corresponding vectors. Let us assume that figures 4① and ② represent a voltage of 1 volt maximum and a current of 1 ampere maximum. On this scale, figure 4③ would then represent a voltage of 3 volts maximum and a 90° leading current of 2 amperes maximum.

d. Figure 5 is a vectorial representation of the current (*i*) and voltage (*e*) in a resistor (both "in phase"). The lengths of the vectors are independent of each other and depend upon the scales selected for each.

FIGURE 5.—Current and voltage in phase.

e. For the capacitor-resistor combination of figure 6①, figure 6② gives the vectorial representation of the current through the circuit and of the voltage across the circuit (voltage lagging the current by less than 90°). The current is uniform throughout the circuit. The voltage at any instant between points 1 and 3 of figure 6① is

the algebraic sum of the voltages existing between 1 and 2 and between 2 and 3. The voltage between 1 and 2 is represented in sine form by the curve marked e_C of figure 7, that between 2 and 3 by the curve



① A. c. generator with capacitance-resistance load.
② Current and voltage vectors for circuit of ①

FIGURE 6.

marked e_R, and the additive resultant, which is the voltage at the generator terminals, by the curve marked e. It is left as an exercise for the student to demonstrate graphically that the vectorial addition

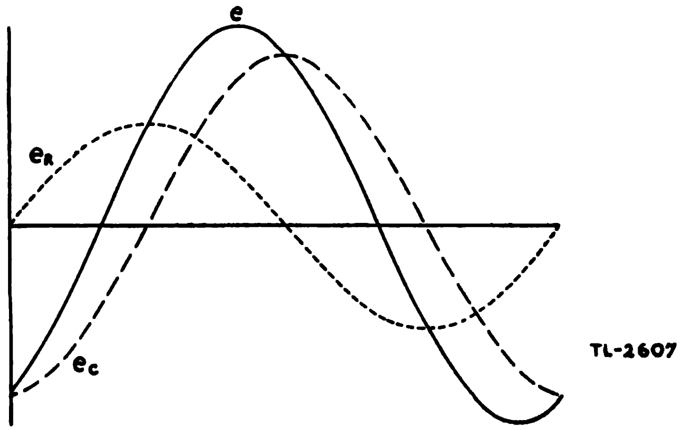


FIGURE 7.—Voltage across capacitor and resistor in series combination in circuit of figure 6①.

of the voltages as shown in figure 8 is equivalent to the detailed addition pictured in figure 7. In general it may be shown that the sum resultant of any two voltage vectors (or of any two current vectors) is represented correctly, both in magnitude and in phase, by the diagonal of the parallelogram formed from the component vectors as in figure 9①, ②, and ③.

7. Circuit containing inductance and capacitance in series.— Among the most important radio circuits is one containing inductance (L) and capacitance (C) in series (fig. 10①). The voltage and current relations which exist in such a circuit are represented vectorially in figure 10②. In magnitude e_L is equal to iX_L, and e_C in magnitude is equal to iX_C. The conditions represented in figure

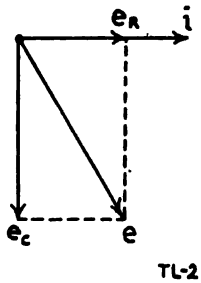


FIGURE 8.—Vector representation of addition corresponding to figure 7.

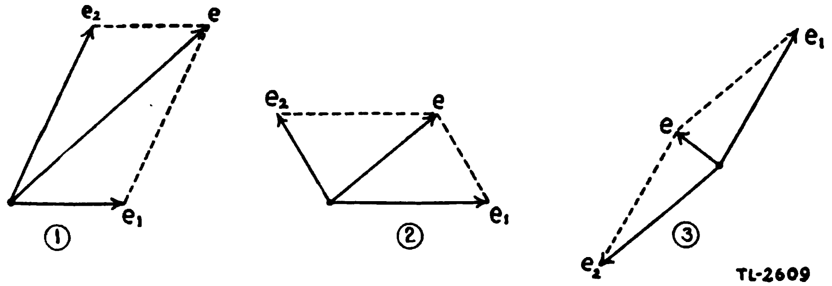
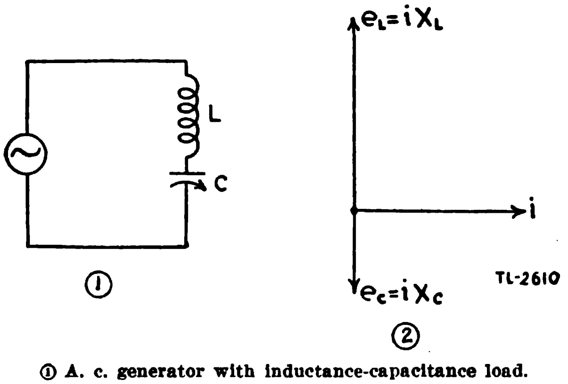


FIGURE 9.—Vector addition of voltages.



① A. c. generator with inductance-capacitance load.
② Current and voltage vectors for circuit of ① under condition of X_L greater than X_C.

FIGURE 10.

10 are such that X_L is greater than X_C; hence e_L is greater than e_C and the net effect in this case is that the series inductance-capacitance combination acts as an inductance alone. This is

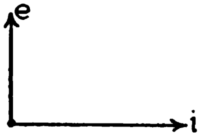


FIGURE 11.—Over-all current and voltage in circuit of figure 10①.

evident on compounding the two voltages to obtain the resultant leading voltage, as in figure 11. If the capacitance is decreased so that the capacitive reactance is increased and the consequent voltage

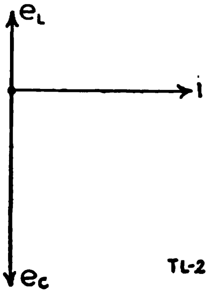
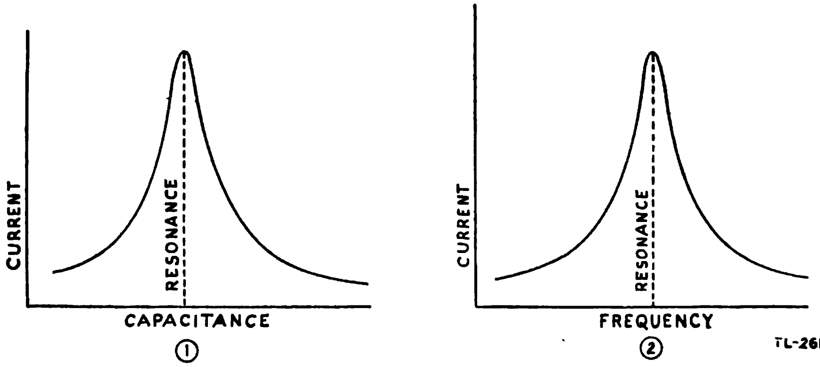


FIGURE 12.—Current and voltage vectors for circuit of figure 10① under condition of X_C greater than X .

across the capacitor increased as in figure 12, then the net effect of the circuit is that of a capacitance alone. In this manner, the react-



① Capacitance varied, inductance and frequency constant.
② Frequency varied, capacitance and inductance constant.

FIGURE 13.—Resonance in series circuit.

ance of the circuit can be varied from inductive to capacitive. When the capacitive and inductive reactances are of equal magnitude, the net reactance of the circuit is zero, a condition described as *resonance.*

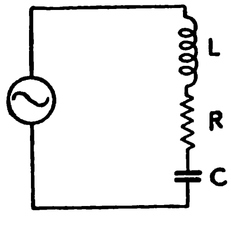
8. Resonance.—*a.* At resonance the current in the circuit of figure 10① becomes infinitely great. This ideal is never attained in practice on account of the presence of resistance. However, even with resistance in the circuit, the current at resonance may reach very large values. As the capacitance (or inductance) is varied either way from resonance, the current falls off as illustrated in figure 13①. Or, if the capacitance and the inductance are fixed, a variation of the frequency of the generator results in a similar variation of current (fig. 13②) with the maximum occurring at that frequency, f_r, for which X_L equals X_C, that is,

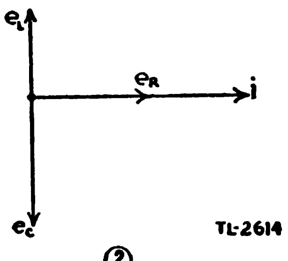
$$2\pi f_r L = \frac{1}{2\pi f_r C}$$

This equation gives for the frequency at resonance

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

b. It should be noted that at resonance, although the resultant potential drop across the complete circuit is relatively low, the voltages across the individual inductive and capacitive branches may be very large, often as much as several hundred times the voltage developed by the generator. This feature of a tuned circuit makes it possible to obtain considerable voltage amplification of radio signals of that particular frequency to which the circuit is resonant. In transmitters, the circuit components, in particular the capacitors, must be chosen to withstand high voltages at resonance.





① A. c. generator with inductance-resistance-capacitance load.
② Current and voltage vectors for circuit of ① under condition of X_C greater than X_L

FIGURE 14.

9. Circuit containing inductance, capacitance, and resistance in series.—*a.* When a series resistor is included in the circuit (fig. 14①), the same considerations as in paragraph 7 hold, with such

modification as is incurred by the addition of a voltage drop across the resistor in phase with the current (fig. 14②). The resultant voltage of figure 14② is obtained by first compounding e_L and e_C (fig. 15①) and then adding this resultant to e_R (fig. 15②).

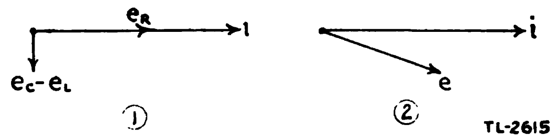


FIGURE 15.—Vectorial addition of voltages of figure 14②.

b. It is convenient to represent reactances in vector form: inductive reactance by an arrow pointing up, capacitive reactance by an arrow pointing down, and resistance by an arrow pointing to the right. Then the net reactance, X, is obtained as the difference between the inductive reactance, X_L, and the capacitive reactance, X_C; the impedance vector, Z $(Z=\sqrt{R^2+X^2})$, is given by the diagonal of the rectangle formed from the vectors X and R. The magnitudes of the individual reactances in the circuit of figure 14① are obtained on dividing the corresponding voltage drops by i:

$$X_C=\frac{e_C}{i}\ X_L=\frac{e_L}{i}\ R=\frac{e_R}{i}$$

The associated vectors are shown in figure 16. The resistance, R, above is the effective a. c. resistance, and is attributed almost entirely to the coil, scarcely at all to the capacitor.

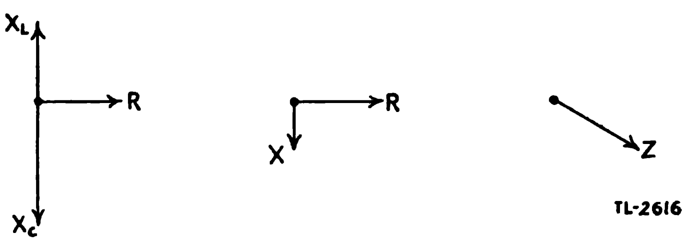


FIGURE 16.—Vectorial addition of reactances to obtain total impedance of circuit of figure 14①.

c. The variation of the net impedance with frequency (L and C fixed) is shown in figure 17. For frequencies below resonance the capacitive reactance is greater than the inductive reactance, and the net effect is that of a capacitance and a resistance in series. At resonance, where the reactances balance, the circuit acts as a pure resistance. For frequencies above resonance the inductive reactance prevails, and the circuit behaves as a simple inductance and a resistance in series.

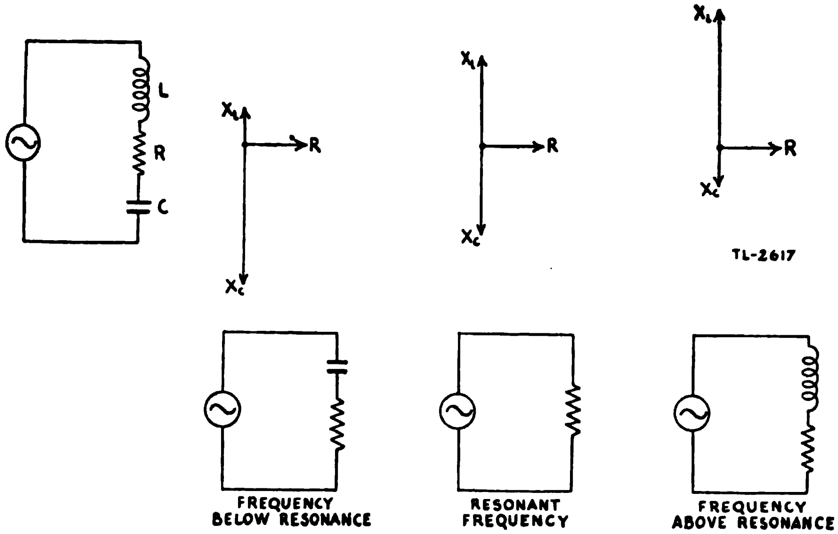


FIGURE 17.—Series circuit. Actual circuit at left. Equivalent circuits for various frequencies below corresponding vector diagrams.

d. It is apparent from figure 18 that if the resistance *R* is very small, the effects of the capacitance and inductance are predominant in determining the net effect of the circuit. At resonance with small cir-

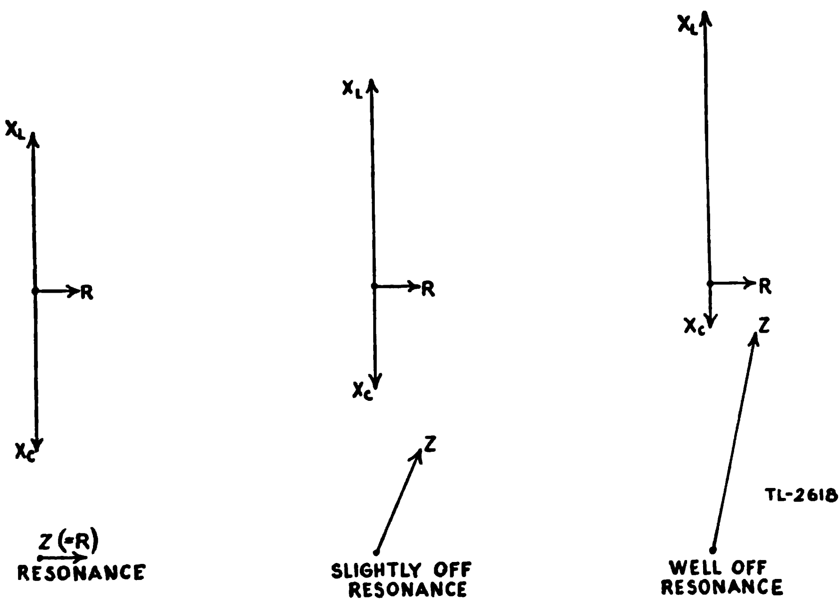


FIGURE 18.—Effect of small resistance on sharpness of resonance for circuit of figure 17. Individual reactances above; net impedance below.

cuit resistance the current is quite large, while slightly off resonance the current drops sharply. On the other hand, if the resistance is large, the resistance predominantly affects the current in the neighborhood of resonance; and the current is only slightly greater at resonance, where the resistance alone is effective, than either side of resonance, where the inductive and capacitive reactances also come into play (fig. 19):

e. Figure 20 illustrates resonance curves for three different values of resistance. These resonance curves demonstrate the practicability of a tuned circuit as a selective device. If voltages of many frequencies

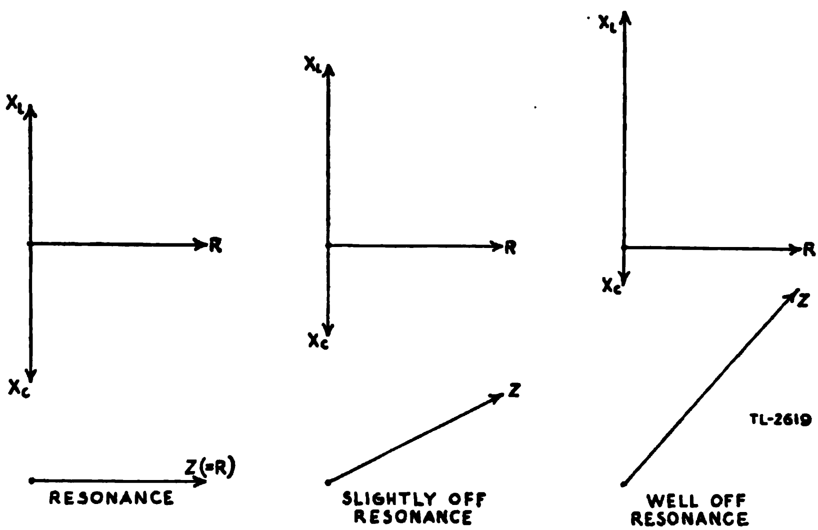


FIGURE 19.—Effect of large resistance on sharpness of resonance for circuit of figure 17. Individual reactances above; net impedance below.

are applied to the tuned circuit, the resulting current is principally of frequencies which are approximately equal to the resonant frequency. As resistance is added to the circuit, the current is attenuated in such a manner that a more nearly uniform but reduced response is obtained over an extended range of frequencies in the neighborhood of resonance. The property of a tuned circuit to accept a limited range of frequencies with essential rejection of all others is called selectivity of the circuit. As shown in figure 20, resistance in the circuit acts to reduce the selectivity. It may be shown that the effect of shunt resistance across either the inductor or the capacitor will likewise reduce the selectivity; the lower the resistance, the poorer the selectivity. Occasionally resistance is deliberately introduced into radio circuits for the purpose of broadening the range of frequencies to which they

are responsive, although generally their inherent resistance is more than enough for this purpose.

10. Circuit containing inductance and capacitance in parallel.—*a.* Whereas in a series circuit the current is uniform and the voltages across the circuit elements are added to yield the total potential drop across the circuit, in a parallel circuit the voltage across each branch is the same, and the separate branch currents are added to yield the total current through the circuit. Consider the parallel circuit of figure 21. At low frequencies, the reactance in the capacitive branch is high, and consequently the current through that branch is low; at high frequencies the reactance is low, and the current is high. In the inductive branch the opposite relations are true.

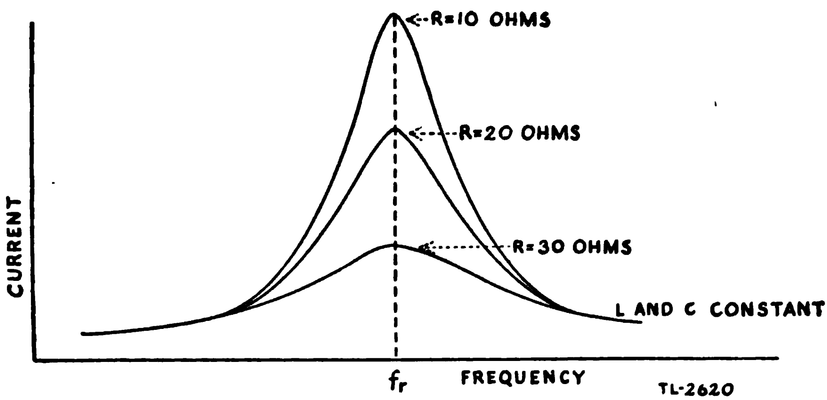


FIGURE 20.—Resonance curves showing broadening effect of series resistance.

b. There are three commonly used conditions for resonance in a parallel circuit. Probably the most common, from a transmitter tuning standpoint, is that resonance is obtained when the line current is a minimum. Another condition is that which makes the impedance of the circuit equivalent to pure resistance. The third condition is that resonance occurs at the frequency for which X_L equals X_C. These three conditions are not identical, but the frequencies obtained by them differ by much less than 1 percent in well proportioned parallel circuits. Therefore, for all practical purposes the resonant frequency of a parallel circuit can be taken as the frequency that satisfies the relation—

$$X_L = X_C$$

or

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

It then follows that the parallel resonant frequency of a tuned circuit is exactly the same as the series resonant frequency of a circuit

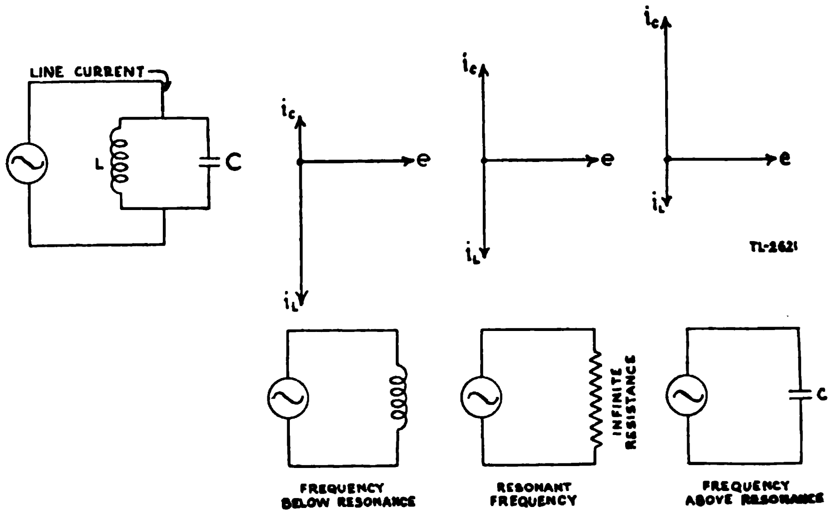


FIGURE 21.—Ideal (no resistance) parallel circuit. Actual circuit at left. Equivalent circuits for various frequencies below corresponding vector diagrams.

composed of the same values of *L*, *R*, and *C* in series. The effective a. c. resistance of the capacitor is frequently negligible, but the resistance of the inductor must be taken into account. Diagrams for

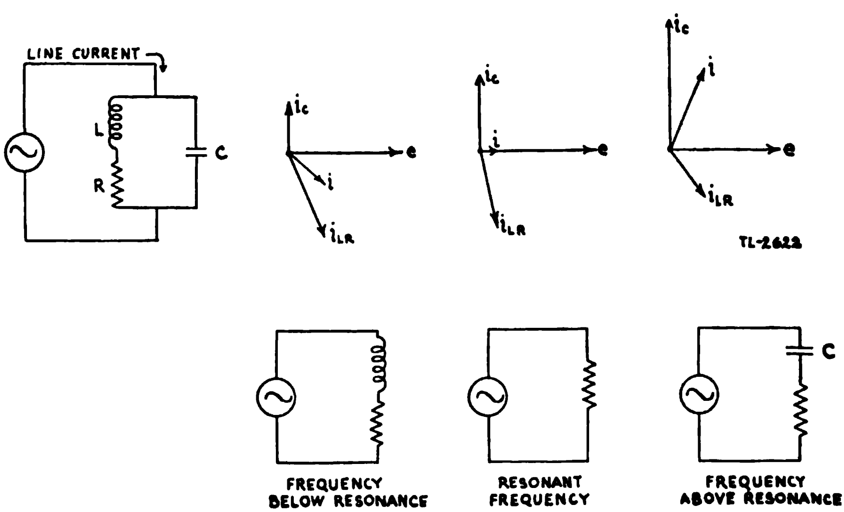


FIGURE 22.—Parallel circuit. Actual circuit at left. Equivalent circuits for various frequencies below corresponding vector diagrams.

this case are shown in figure 22. At frequencies below resonance the net line current may be resolved into an in-phase component and a lagging component; that is, the circuit is equivalent to a simple inductance-resistance series combination. At frequencies above resonance the net current may be resolved into an in-phase component and a leading component; that is, the circuit is equivalent to a simple capacitance-resistance combination. At resonance, that is, for X_L equal to X_C, the net line current, at least in the practical case of R very much smaller than X_L, is essentially in phase with the applied voltage, and the circuit acts substantially as a pure resistance. Due to the presence of resistance the actual lagging current at resonance is very slightly less than the leading current. However, for most practical purposes it is adequate to consider the lagging and leading components as equal at the frequency of resonance.

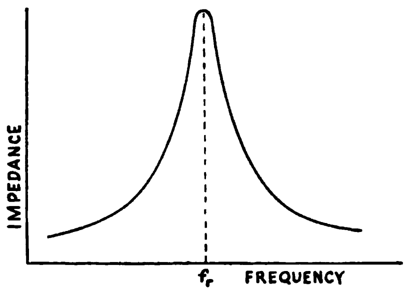


FIGURE 23.—Resonance curve for a parallel tuned circuit.

c. Resonance in a parallel circuit is often referred to as antiresonance because of the inverse relations as compared with the series case. At resonance the series circuit presents a very low resistance, the parallel circuit a very high resistance; at frequencies below the resonant frequency the series circuit behaves as a capacitance, the parallel circuit as an inductance; and at frequencies above the resonant frequency the series circuit behaves as an inductance, the parallel circuit as a capacitance. The resonance curve of a series circuit in which current is plotted against frequency (fig. 13②) resembles in shape the resonance curve of a parallel circuit in which impedance is plotted against frequency (fig. 23).

d. It will be found that the selectivity of the parallel circuit is inversely related to the resistance in either individual branch of the circuit. Further, the selectivity is adversely affected by a resistance shunted across the entire circuit; the lower the resistance, the broader the response.

e. In a circuit as in figure 24, for a fixed frequency of the generator potential, a variation of the capacitor C is accompanied by a variation of the ammeter reading as the over-all impedance of the circuit changes. Minimum current in the line indicates antiresonance and maximum circulating current within the LC circuit. A parallel resonant circuit in a radio transmitter is tuned in this

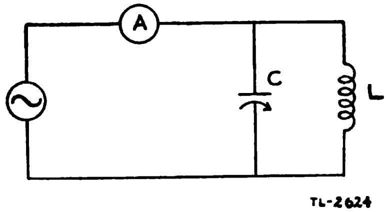


FIGURE 24.—Minimum ammeter reading indicates resonance.

manner by watching for a dip in the line current or ammeter reading.

f. For the parallel circuit in the practical case of R relatively small, a detailed study yields for the over-all impedance (resistance) at resonance

$$R_o=\frac{L}{RC}$$

that is, the net impedance at resonance is equivalent to a resistance, the magnitude of which is directly proportional to the ratio of L to

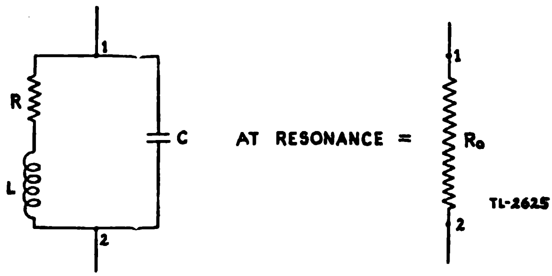
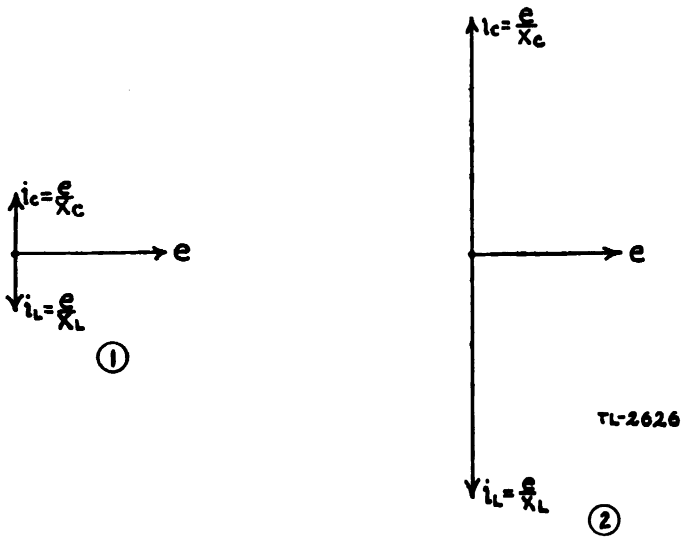


FIGURE 25.—Equivalent circuits at resonance.

C and inversely proportional to R. The reasonableness of this equation may be attested to, at least, by an examination of the current-voltage relations for special cases. Resonance implies merely $X_L=X_C$. Table I lists some of the possible combinations of L and C which correspond to resonance at a frequency of 10,000 kilocycles. For R equal to zero, R_O is infinite for any L to C ratio. This is apparent on examination of figure 26, which shows vector diagrams for resonance, corresponding ① to $X_L=X_C$ large and ② to $X_L=X_C$

small. In either case no current flows from the generator into the tuned circuit regardless of the applied potential; that is, in either case the resistance of the tuned circuit at resonance is infinite. When R is not zero and X_L is large $\left(\frac{L}{C}\text{ large}\right)$, the net current i and consequently the resistive component i_R are small, so that the effective resistance of the tuned circuit is large. When R is not zero and X_L is small $\left(\frac{L}{C}\text{ small}\right)$, i and i_R may be large, indicating a small effective resistance of the tuned circuit.



① High $\frac{L}{C}$. ② Low $\frac{L}{C}$.

FIGURE 26.—Antiresonance in ideal (no resistance) circuit.

TABLE I

L (microhenrys)	C (micromicrofarads)	$X_L=2\pi f_r L$ (ohms)	$X_C=\frac{1}{2\pi f_r C}$ (ohms)
0.1	2,533	6.28	6.28
1	253	62.83	62.83
10	25.3	628.3	628.3
100	2.53	6,283	6,283

11. "Q."—*a.* The merit of an inductor (coil) in a circuit is most conveniently expressed as the ratio of the inductive reactance to the

effective a. c. resistance of the coil. This ratio is so important in the theory of resonant circuits that it is considered as a fundamental property and is usually referred to by the symbol Q. Since the total inductance and resistance of a circuit are almost entirely concentrated in the coil, Q may be represented as follows:

$$Q=\frac{2\pi fL}{R}=\frac{X_L}{R}$$

The effective resistance R of the coil includes any dielectric loss which the coil might have; however, in a well-designed coil the R is due almost entirely to skin effect. Two coils of identical shape can have different Q's if their resistances differ; or two coils of the same resistance can have different Q's, if their inductances differ. The Q of any given coil remains practically constant over a wide range of frequencies, because the effective a. c. resistance of a coil is roughly proportional to the frequency, while the inductive reactance is exactly proportional to the frequency. Typical radio inductors have Q's of the order of 100 to 800, depending upon the nature of the service for which they are designed.

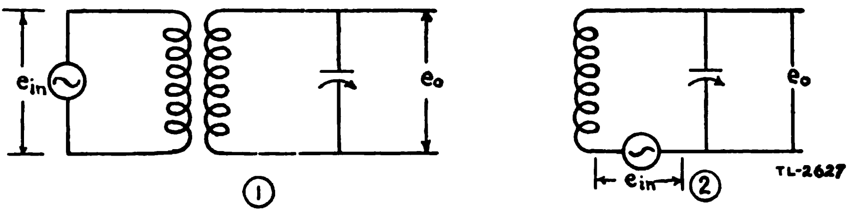
b. At resonance in a parallel tuned circuit the net resistance is Q times the reactance of either of the branches. This follows from the equation—

$$R_0=\frac{L}{RC}=\frac{L}{RC}\times\frac{2\pi f_r}{2\pi f_r}=\frac{X_CX_L}{R}=X_CQ=X_LQ$$

Thus the current through either reactor at resonance is Q times the net line current. In the series circuit at resonance the potential across each reactor is Q times the net potential across the complete circuit. This is apparent from the fact that the ratio of the voltages in a series circuit is equal to the ratio of the reactances. Since the net impedence offered by the series circuit at resonance is equal to that of the resistance alone, the potential across either reactor is Q times the net applied line potential. For either parallel or series tuned circuits a high Q, that is, relatively low R, implies good selectivity.

12. Coupled circuits; voltage gain.—*a.* A common form of coupled circuit arrangement for radio receivers is that of figure 27. The voltage gain at the resonant frequency of this circuit, that is, the ratio of output voltage to input voltage, is the product of the individual voltage gains in the transformer and in the tuned circuit. If the voltage gain of the transformer is unity, so that the induced voltage in the secondary is equal in magnitude to the applied voltage in the primary, then the gain of the circuit is equal to Q, as explained

in paragraph 11*b*. The voltage gain of this circuit is no violation of the principle of the conservation of energy. Energy is alternately exchanged between the inductor and the capacitor, and the only power dissipated is that which is converted into heat by the inherent resistance of the circuit. This latter is the only power which the primary circuit is called upon to supply. If energy is drawn from the tuned circuit, for example, to supply a third circuit, the potential across the secondary output will drop to a value consistent with the available input power, which in radio receiver circuits is apt to be quite small.



① Common form of coupled circuit arrangement for radio receivers.
② Equivalent circuit for unity coupling.

FIGURE 27.

b. One tuned circuit is frequently coupled to another, as in figure 28. The over-all frequency characteristic—that is, secondary current versus frequency for a given magnitude of applied primary voltage—depends upon the degree of coupling employed. If each circuit is independently tuned to the same frequency and then the circuits are

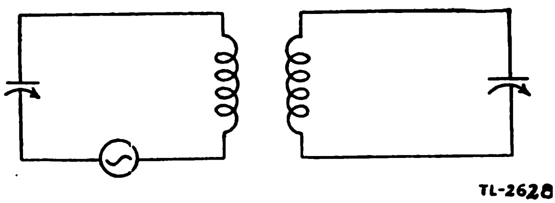
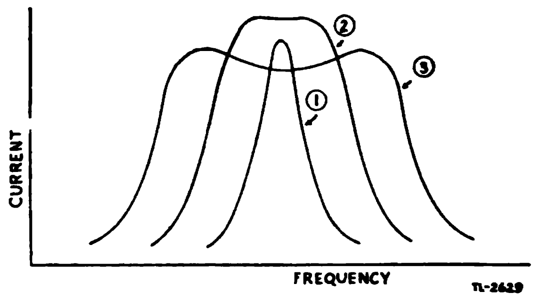


FIGURE 28.—Inductively coupled tuned circuits.

loosely coupled together, the over-all frequency characteristic is similar to the resonance curve for an isolated series circuit (figure 13②). However, if the coupling is sufficiently increased, for instance, by winding the secondary coil directly over the primary coil, the over-all reactance and the effective resistance are so altered that a double-humped frequency characteristic results, one peak occurring on either side of the frequency to which the circuits were individually tuned. A compromise (fig. 29②) is often struck be-

tween very loose (fig. 29①) and very tight (fig. 29③) coupling to permit nearly uniform energy transfer over a particular restricted range of frequencies. The selectivity of a coupled circuit is adversely affected by the presence of resistance across or in series with any part of the circuit. The effect is similar to that for an individual tuned circuit (fig. 20), a high series resistance or a low shunt resistance producing the broadest tuning.



① Loose coupling. ② Intermediate coupling. ③ Tight coupling.

FIGURE 29.—Frequency characteristics of coupled circuits.

SECTION III

FILTERS

13. Filter action of individual capacitors, inductors, and resistors.—The analysis in section II indicated the feasibility of using resonant circuits for selecting energy at desired frequencies and for rejecting energy at undesired frequencies. Certain other inductor-capacitor arrangements are better adapted to passing or rejecting more or less uniformly a wide band of frequencies.

a. In the circuit of figure 30 the applied potential consists of three components: direct current, e_{dc}; audio frequency alternating current, e_{af}; and radio frequency alternating current, e_{rf}. The current which flows is given by

$$i=\frac{e_{dc}}{Z_{dc}}+\frac{e_{af}}{Z_{af}}+\frac{e_{rf}}{Z_{rf}}$$

where Z_{dc} is the impedance (or rather the resistance) of the load to direct current, Z_{af} is the impedance of the load to current of the frequency of e_{af}, and Z_{rf} is the impedance of the load to current of

the frequency of e_{rf}. The internal impedance of the source is here neglected. If the load is capacitive, and hence offers infinite impedance to direct current and low impedance to alternating current, the current which flows contains only a. c. components; the magni-

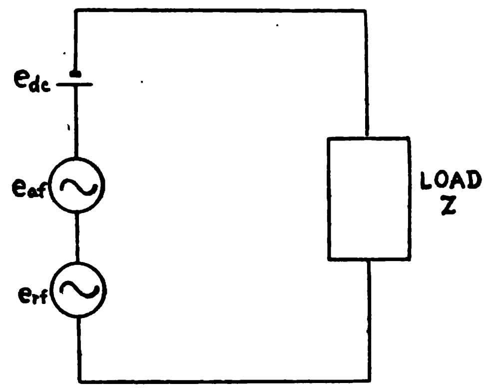


FIGURE 30.—Potential of three frequency components applied to load.

tude of the audio frequency (a. f.) component is proportional to its frequency, as is the magnitude of the radio frequency (r. f.) component proportional to its frequency. On the other hand, if the load is inductive, the radio frequency and alternating frequency components of current are each inversely proportional to their respective

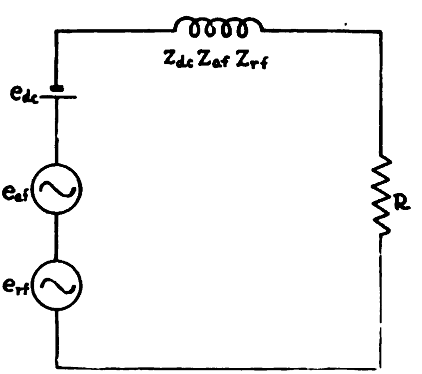


FIGURE 31.—Low pass filter.

frequencies, and the magnitude of the direct current component is limited only by the inherent small resistance of the inductor.

b. In the following circuits take the internal resistance of the source as negligible; the impedances of the inductor, *L*, as: Z_{dc} zero, Z_{af}

very much smaller than R, Z_{rf} very much greater than R; the impedances of the capacitor as: Z_{dc} infinite, Z_{af} very much greater than R, Z_{rf} very much smaller than R. These relative impedances are possible because of the wide difference in frequency between radio frequencies and audio frequencies. Take the potentials, e_{dc}, e_{af}, and e_{rf} as approximately equal in magnitude. The total impedance of the circuit of figure 31 is relatively high to r. f. currents (impedance determined principally by Z_{rf}; R negligible in comparison with Z_{rf} and relatively low to direct and a. f. currents (impedance determined principally by R; Z_{af} and Z_{rf} negligible in comparison with R). Thus the coil, L, effectively serves to "choke" the r. f. current and may be regarded as a simple low pass filter.

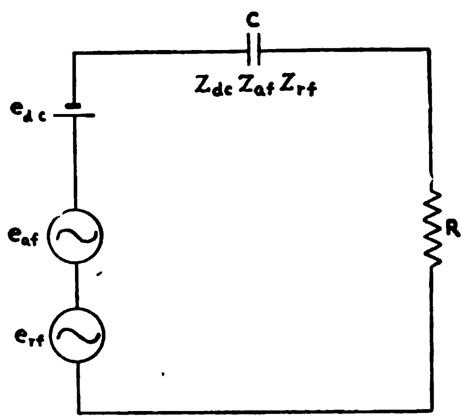


FIGURE 32.—High pass filter.

c. The total impedance of the circuit of figure 32 is infinite to direct current and relatively high to a. f. currents (the effect of R is negligible in either case) and relatively low to r. f. currents (impedance determined principally by R). The capacitor effectively "blocks" direct current and may be regarded as a simple high pass filter.

d. In the circuit of figures 33 and 34 the series resistor R is of the same resistance as the load resistor. In the circuit of figure 33 the impedance of the parallel branch is essentially only R to direct current and to a. f. currents, and Z_{rf} to r. f. currents. The potential e_{dc} is then divided equally, $\frac{e_{dc}}{2}$ across the load resister and $\frac{e_{dc}}{2}$ across the series resistor. A similar division of potential obtains for the audio frequency voltage, e_{af}. However, e_{rf} is almost entirely

across the series resistor, because the impedance of the parallel circuit to r. f. currents (essentially Z_{rf}) is very small. Thus only a small fraction of e_{rf} occurs across the load resistor and consequently very little r. f. current flows through the load resistor. The student will

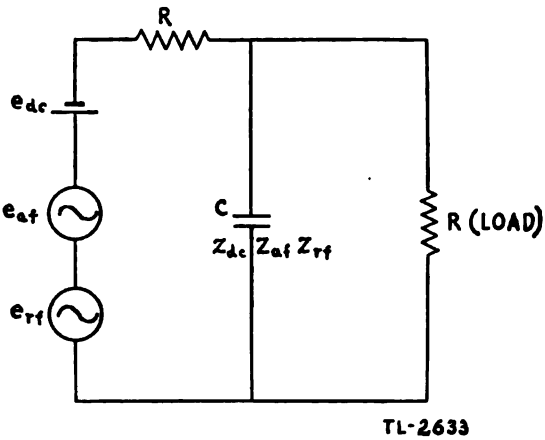


FIGURE 33.—Low pass filter.

find it worth while to demonstrate for himself that the inductor and the series resistor in the circuit of figure 34 act as a high pass filter.

e. Figure 35 presents a pictorial concept of currents which flow in series circuits corresponding to various applied potentials.

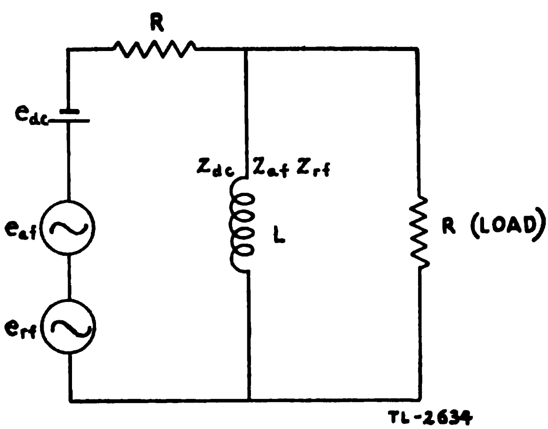


FIGURE 34.—High pass filter.

14. Filter action of resonant circuits.—Resonant circuits can be made to serve as filters in a manner similar to the individual inductors and capacitors of paragraph 13. The series resonant

circuit offers a very low impedance to currents of the particular frequency to which it is tuned, and a relatively high impedance to currents of other frequencies. A series resonant circuit replacing the inductor of figure 31 would act as a band pass filter, passing

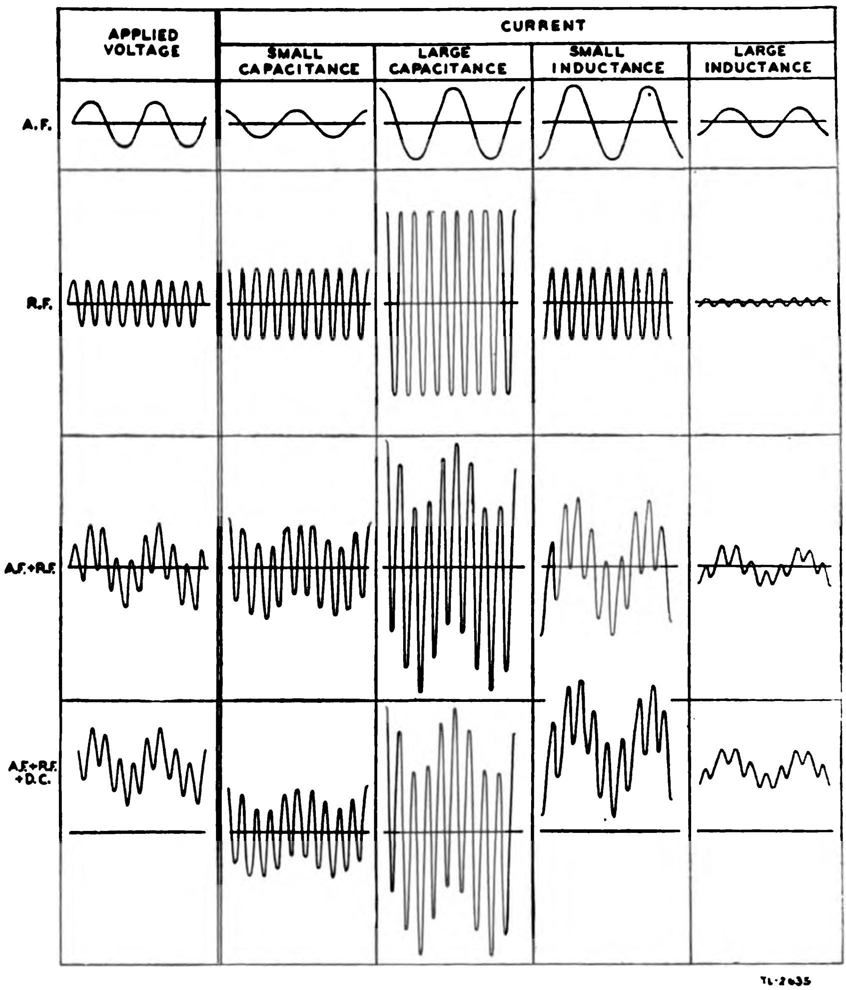


FIGURE 35.—Filter action of individual series capacitances and inductances

currents of frequencies in the neighborhood of its natural frequency and attentuating all others. A series resonant circuit shunted across the load to replace the inductor of figure 34 would bypass currents of its natural frequency. The parallel tuned circuit, on the other hand, offers a very high impedance to currents of its natural fre-

quency and a relatively low impedance to others. In series with a load it acts as a band stop filter; in parallel with a load as a band pass filter.

15. General filter networks.—*a.* Combinations of capacitances, inductances, and resistances are frequently used in networks. The arrangement of figure 36 is commonly employed to "smooth" the output of rectifier tubes supplying plate current for a transmitter or receiver. The capacitors shown are each of 10 microfarads

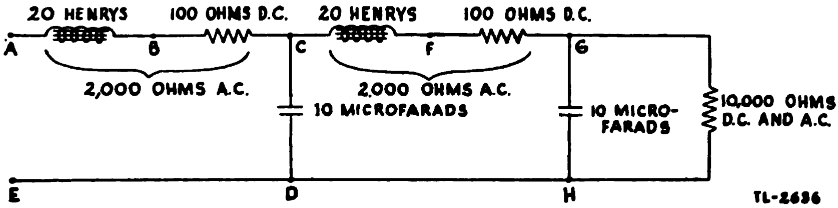
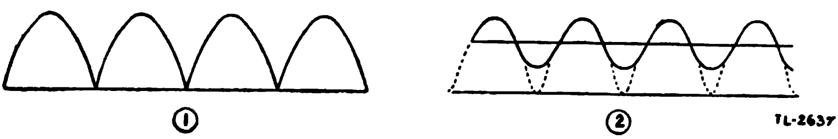


FIGURE 36.—Low pass filter for power supply.

capacitance; and each choke is of 20 henrys inductance with inherent resistance of 100 ohms to direct current and total impedance of 2,000 ohms to 120-cycle alternating current. The load is a 10,000-ohm (d. c. or a. c.) resistance. A semi-quantitive analysis of the action of such a filter may be made as follows. The impressed voltage at AE (voltage output of a full-wave rectifier), which is actually shown in figure 37①, may be regarded as roughly equivalent to a superposition of two simple voltages, one a direct voltage and the



① Actual voltage input filter. ② Approximate equivalent voltage input to filter.

FIGURE 37.

other a 120-cycle alternating voltage as in figure 37②. That much of the filter which is to the right of CD (fig. 36) is of sufficiently high 120-cycle impedance so that its contribution to the total impedance across CD is negligible. Thus for studying the ripple component, the filter may be studied in isolated sections as shown in figure 38. The relative alternating voltage drops across the inductance, resistance, and capacitance of the first section are as represented in figure 39. For the first section the ratio of alternating voltage output to input, $\frac{e_{GH}}{eAE}$, may be of the order of 1 percent.

In the output of the second section, that is, in the voltage across the load, any ripple component is negligible. On the other hand, the only d. c. resistance which the complete filter offers is the rela-

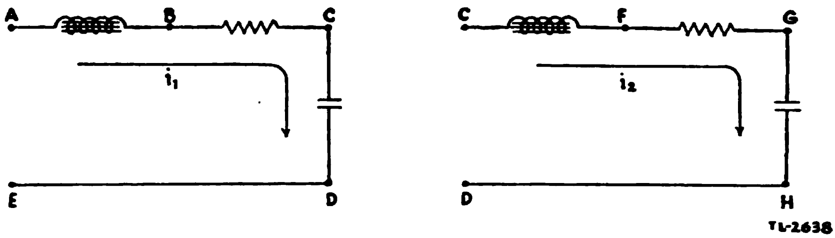


FIGURE 38.—Low pass filter in sections.

tively small total d. c. resistance (200 ohms), so that nearly the full continuous voltage across the filter input is impressed on the load,

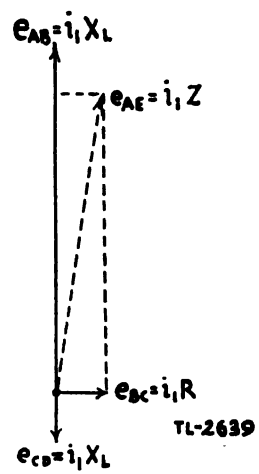


FIGURE 39.—Alternating voltages in first section of low pass filter.

The voltage output of the first section is shown in figure 40①. and the output of the second section in ②.

① First section. ② Second section.

FIGURE 40.—Voltage output of low pass filter sections.

b. A high pass filter is shown in figure 41. Band pass and band stop filters employing resonant circuits are shown in figures 42 and 43 respectively.

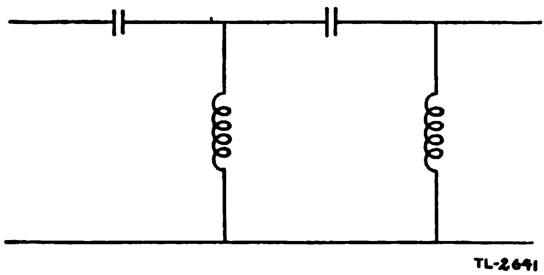


FIGURE 41.—High pass filter.

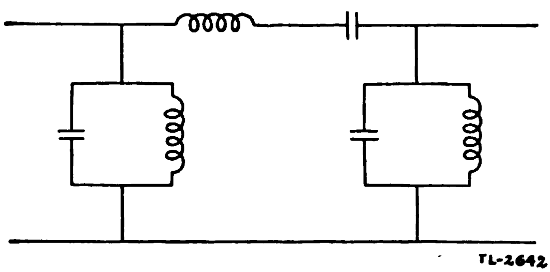


FIGURE 42.—Band pass filter.

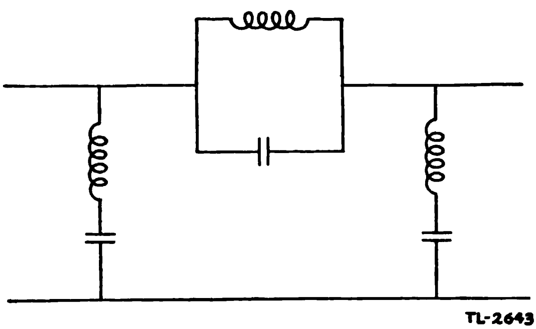


FIGURE 43.—Band stop filter.

Section IV

VACUUM TUBES

16. General.—*a.* Tungsten and certain other metals and metallic oxides yield electrons freely when heated to a high temperature in a low-pressure atmosphere. Any isolated positively charged body in the vicinity of an electron emitter attracts the electrons, which then ultimately neutralize the positive charge. The positive charge can be

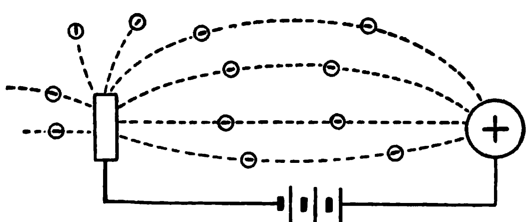


Figure 44.—Emitted electrons attracted by positively charged body.

maintained, however, if electrons are removed just as fast as they strike, as, for example, by connecting a source of constant voltage between the positively charged body and the emitter (fig. 44). This is the general arrangement in a two-element vacuum tube (*diode*). The emitter may resemble the familiar incandescent lamp filament heated by passing a current through it. The charged body usually surrounds the emitter and is called the *plate*. The whole assembly is enclosed in an evacuated glass or metal container, called the "envelope." The plate, being the terminal at which current normally enters the tube, is sometimes called the *anode;* the emitter, being the terminal at which current normally leaves the tube, is commonly called the *cathode.*

(The conventional direction of current flow is opposite to the direction of electron motion.)

b. The pressure inside a vacuum tube is reduced to such an extent that only about $1/100,000,000$ of the original air in the tube remains. For pressures much above this amount spurious effects are introduced by the presence of gas molecules. The electrons are deflected from their normal paths by collisions with gas molecules; the positive ions formed from the molecules as the result of such collisions make for background noise in a radio receiver; these positive ions further serve to lower the internal resistance and amplifying power of a vacuum tube, and they may lower the effectiveness of an emitter or even destroy it. In general, tubes are evacuated to the highest extent consistent with economical commercial manufacture.

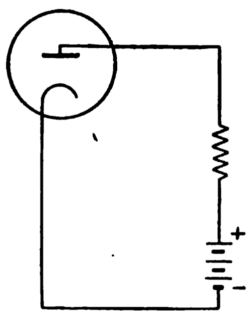


FIGURE 45.—Diode with resistive load.

17. Diode rectifier.—The symbolic representation of a diode with a resistive load is as shown in figure 45. The battery potential controls the magnitude of the current through the load resistance. Increasing the potential increases the rate at which the emitted electrons move to the plate and the rate at which current flows through the load; decreasing the potential decreases the current through the load. Reversing the potential, which makes the plate negative with respect to the emitter, causes repulsion of the electrons from the plate with consequently no current through the load. One immediate application of the vacuum tube is obvious: its use as a rectifier. Thus with an alternating potential applied (fig. 46), current flows through the load only during alternate half cycles; that is, when the plate is positive with respect to the emitter—and only in one direction, from plate to emitter (fig. 46).

18. Characteristic curves.—The load current in the above circuit is not proportional to the applied voltage, as is the case with pre-

viously studied circuits. Ohm's Law is strictly applicable only to small increments of currents and voltages, and current-voltage relations in general in vacuum tube circuits are studied by means of experimentally obtained characteristic curves. A plot of the direct current in the load of figure 45 against the plate-to-emitter potential is shown in figure 47. At the lower values of plate potential the

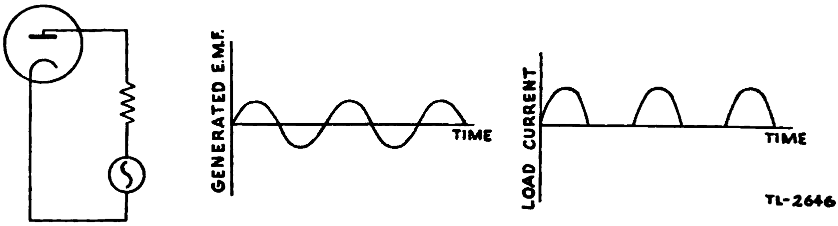


FIGURE 46.—The diode as a rectifier.

accumulated emitted electrons in the neighborhood of the cathode are effective in repelling the electrons nearest the cathode back toward the cathode, and only those electrons which are nearest the plate are attracted to the plate. For intermediate values of plate potential the space charge in the vicinity of the cathode is reduced, owing to

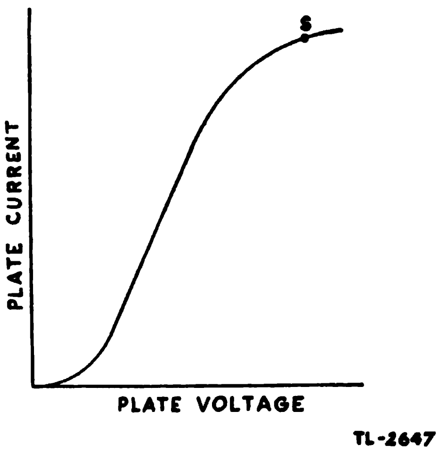
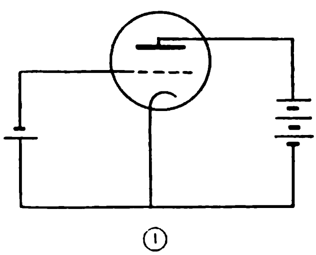


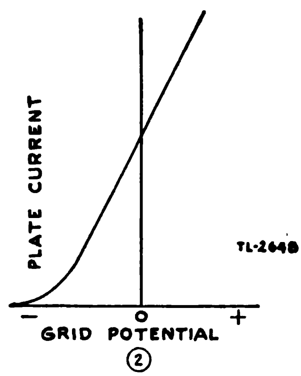
FIGURE 47.—Plate current-plate voltage characteristic of diode.

the removal of increased numbers of electrons, by the attraction of the positively charged plate, and any increase in plate potential produces an appreciable increase in current. For large values of plate potential, when the space charge is completely removed, the number of electrons reaching the plate per second is limited by the number emitted per second from the cathode, and is independent of

plate potential. This condition is referred to as saturation, and a point S on the knee of the plate current-plate voltage curve is called the saturation point.

19. Triode amplifier.—The plate current of a vacuum tube is conveniently varied by applying a positive (with respect to the cathode) potential to a mesh type element located between the plate and cathode and in the space charge region. Such an element, termed a grid because of its usual gridiron-like structure, tends to reduce the effect of the space charge in a manner similar to the action of the plate. However, due to the highly effective location of the grid in proximity to the cathode and to the space charge center, it is much more efficient than the plate in accomplishing this mission. At the same time, the open structure of the grid permits the ready





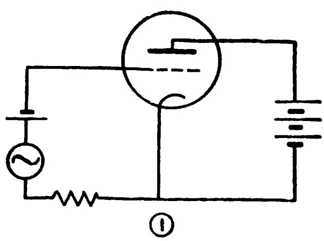
① Basic triode circuit. ② Plate current vs. grid potential characteristic.

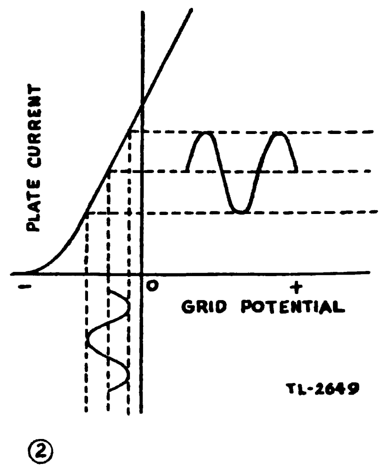
FIGURE 48.

passage of electrons through it and onto the plate. The net effect is that for a fixed positive plate potential, a small positive grid potential makes for large plate current; and a small negative grid potential is sufficient to counterbalance the positive plate potential and to reduce the plate current to zero. A second application of the vacuum tube is apparent: its use as a relay and amplifier. Large current variations in the load circuit may be made to follow relatively small voltage variations across grid to cathode. The manner in which plate current varies with grid potential is illustrated in the characteristic curve of figure 48 for a three element tube (triode).

20. Distortion.—If in the circuit of figure 48① an alternating voltage (signal voltage) is superimposed on the direct voltage (grid bias) as in figure 49①, the variations in the plate current will follow a pattern similar to the variations in grid voltage (fig. 49②).

Provided the grid potential swing is within the limits of the straight line portion of the characteristic, the plate current will faithfully reproduce the grid potential form. However, if the grid is allowed to go positive so that current flows in the grid circuit, the grid to cathode a. c. potential differs in form from the actual signal potential because of the drop in potential occurring with the flow of current across any impedance which is in the grid circuit. Unless some compensation for the effects of grid current is provided, in order to avoid distortion the grid swing must be restricted not merely to the straight line portion of the characteristic but to only negative values as well.





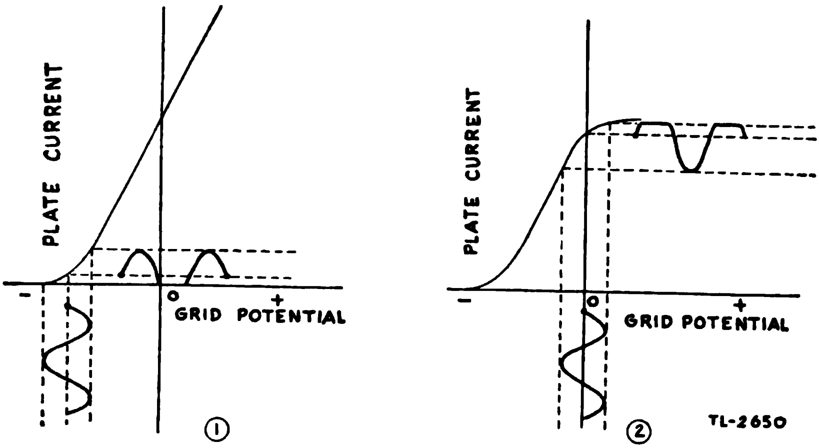
① Triode with impressed signal voltage. ② Output current vs. input voltage.

FIGURE 49.

Distortion also results either if the grid bias is increased excessively as in figure 50①, or if the cathode temperature is lowered so that the emission is insufficient, as in figure 50②. A distorted output is generally, but not always, objectionable, occasionally it is actually desirable.

21. Static and dynamic characteristics.—In figure 51 there are shown for comparison two characteristics of a triode, one for the case of no load in the plate circuit (static characteristic) and the other for the case of a load in the plate circuit (dynamic characteristic). The difference in the slope of the two curves is due to the fact that the plate-to-cathode potential for no load is constant regardless of the plate current, whereas with a load in the plate circuit the potential across the load, and consequently the plate to cathode potential, varies with the

current. Take the normal operating point as the same for the tube either with or without external load, that is, regard the operating point as the point of intersection of the two curves of figure 51. Without an external load, as in figure 52①, on a positive swing, of signal potential,



① Effect of high grid bias. ② Effect of low cathode temperature.

FIGURE 50.

A, figure 52③, the plate current rises by an amount *B*. With an external load, as in figure 52②, the increase in current which follows a positive grid swing is in turn accompanied by a potential drop (*IR*) across the load (as read by voltmeter V_2). Thus the potential available across plate to cathode within the tube (as read by voltmeter

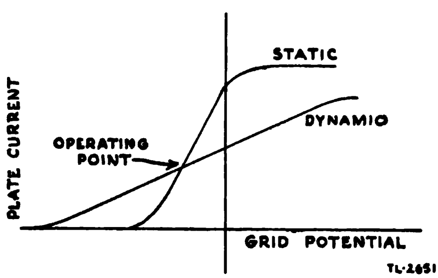
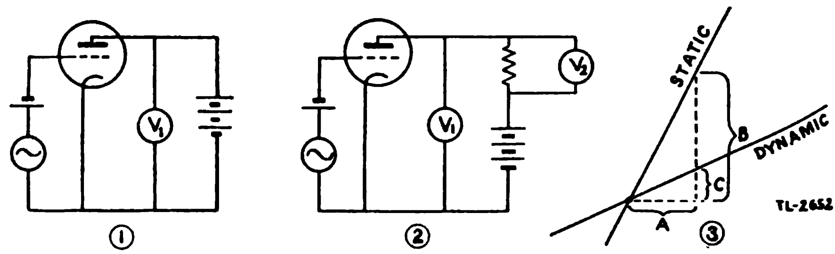


FIGURE 51.—Static and dynamic characteristics of triode.

V_1) is reduced; and the consequent increase in current *C* is less than it was under the no load condition. On the negative half cycle of the signal voltage the plate current is reduced, and the potential drop across the load is less than it is under normal operating conditions. Thus the voltage across the tube rises, so that the available plate to

cathode potential exceeds the corresponding value under the no load condition. The dynamic curve is, incidentally, more nearly linear than is the static curve.

22. Miscellaneous characteristics.—Three dynamic curves are given in figure 53 for various load resistances. A set of static curves



① With external load. ② Without external load. ③ Corresponding characteristics.

FIGURE 52.—Triode.

is shown in figure 54 for various plate potentials. A set of characteristics frequently useful in circuit design is a group of static plate current-plate voltage curves for various grid potentials as shown in figure 55. Many handbooks on vacuum tubes confine the characteristics illustrated to *families* of curves of this last type.

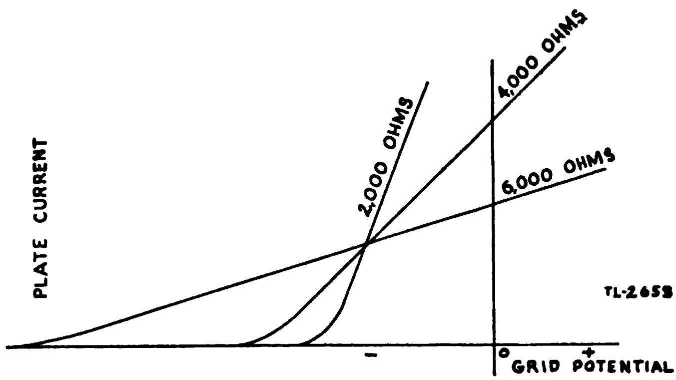


FIGURE 53.—Dynamic characteristics of triode.

23. Families of characteristics used in analysis.—Observe that of the three quantities, grid potential, plate potential, and plate current, any two will determine the third from the set of static characteristic curves of figure 55. Thus corresponding to a plate current of 10 milliamperes and a plate potential of 50 volts, the required grid potential is −8 volts. Suppose it is desired to obtain these same relations—plate current 10 milliamperes, plate potential 50 volts, and

grid potential −8 volts—with a load resistance of 4,000 ohms. This requires a total plate supply potential of $50+4000\times(10/1000)$ volts= 90 volts, 50 across the tube and 40 across the load resistance. The current in the load resistance follows Ohm's Law, that is, the current through the resistance is proportional to the potential across it. This proportionality can be represented by a straight line on the current-

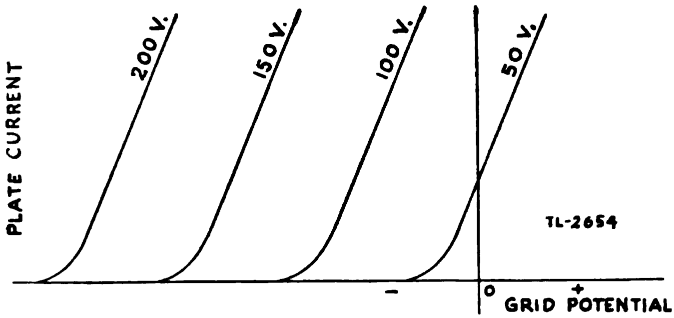


FIGURE 54.—Plate current vs. grid potential curves for triode.

voltage graph of figure 56. The line is determined by any two points on it, two convenient points being *P* and *Q*, as in figure 56①. *P* is for a current of 10 milliamperes and a voltage drop across the resistance of 40 volts (50 volts across the tube); *Q* is for zero current and zero drop across the resistance (90 volts across the tube). If *P* is taken as the normal operating point, the grid swing due to an im-

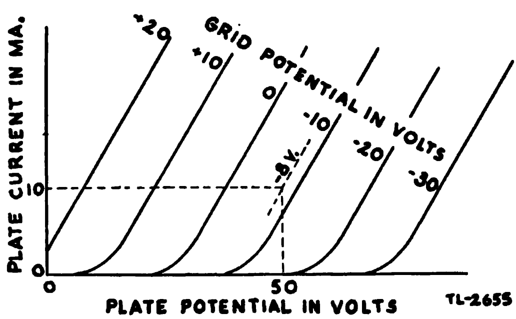
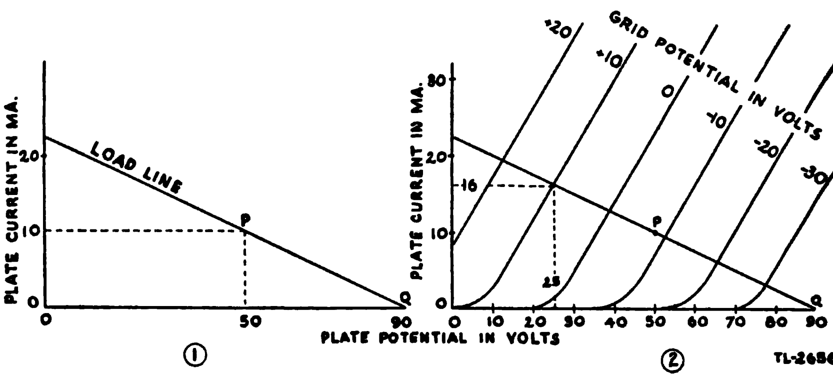


FIGURE 55.—Plate current vs. plate potential curves for triode.

pressed signal voltage will cause variations along this load line in both directions from *P*. Corresponding to an instantaneous grid potential of 10 volts, the plate current, plate voltage, and voltage across the load can be found by following the 10-volt characteristic to where it intersects the load line. From the curves of figure 56② this yields 16 milliamperes plate current, 25 volts plate potential, and

90 − 25 = 65 volts drop across the load. The family of plate current-plate potential curves is thus useful in determining the limitations of a particular tube under various operating conditions. A particular tube can be selected to fit certain circuit constants, or vice versa, with the aid of the information contained in the vacuum tube characteristics.

24. Resistance, amplification factor, and transconductance.—The a. c. internal resistance, R_p, of a vacuum tube is measured by the increase in plate voltage required to produce given increase in plate current. A tube for which a 10-volt plate potential increase is required to produce a 10-microampere increase in plate current has a relatively high internal resistance, $\frac{10}{0.000010} = 1{,}000{,}000$ ohms. A tube which requires a 10-millivolt plate potential increment to



① Construction. ② Application.

FIGURE 56.—Load line.

produce a 10-microampere plate current change has a relatively low internal resistance, $\frac{0.010}{0.000010} = 1{,}000$ ohms. Low internal resistance is manifested by a steep i_p–e_p characteristic corresponding to large increases in plate current for small increases in plate voltage. The amplification factor, μ, (a Greek letter, "mu") of a tube is a measure of the relative effectiveness of grid and plate potential increments in changing the plate current, and is an indication of the suitability of the tube for voltage amplification purposes. If a 1 milliampere increase of plate current is accomplished either by a 10-volt increase in plate potential or by a 0.1 volt increase in grid potential, the amplification factor is $\frac{10}{0.1} = 100$. Transconductance, G_m, is defined as the ratio of a small change in plate current to the change in grid potential

producing it, all other voltages remaining constant. Transconductance is a criterion of the suitability of a tube for power amplification purposes, a tube with a high transconductance yielding large plate current variations corresponding to small variations in grid potential. The transconductance of a tube is dimensionally a ratio of amperes to volts and is thus measured in reciprocal ohms or mhos. ("Mho" is "ohm" spelled backwards.) A tube with a high transconductance, perhaps 10,000 micromhos, is evidenced by a steep i_p–e_g characteristic; a tube with a low transconductance, perhaps 10 micromhos is shown by an i_p–e_g characteristic with a small slope. Internal resistance, amplification factor, and transconductance are interrelated, amplification factor being essentially a product of the other two. A tube which has both a high transconductance and a high internal resistance accomplishes the same increase in plate current with a small increase in grid potential alone (due to the high transconductance) as with a large increase in plate potential alone (due to the high internal resistance). In other words, such a tube also has a high amplification factor.

25. Interelectrode capacitance.—The inherent capacitance between grid and plate elements of a triode is of sufficient importance at high frequencies to require special consideration in radio circuits. Where this capacitance is undesirable, it can be counteracted by introducing a neutralizing circuit which presents r. f. potentials equal in magnitude but opposite in phase to those occurring across the interelectrode capacitance, with the result that the effects of the interelectrode capacitance are nullified. The extra circuit complications can generally be avoided by the use of tetrodes or pentodes, four and five element tubes respectively, which are particularly designed to have low interelectrode capacitance. The grid to plate capacitance of an ordinary receiving triode runs about 3 micromicrofarads. This represents a capacitive reactance of 53,000 ohms at 1 megacycle and only 530 ohms at 100 megacycles. Tetrodes and pentodes offer corresponding reactances of about 16,000,000 ohms at 1 megacycle and 160,000 ohms at 100 megacycles.

26. Tetrodes.—The tetrode includes a second grid, called a screen grid, between the regular control grid and the plate. The screen grid is operated at a potential which is positive with respect to the cathode but less positive than the plate. By connecting the screen to the cathode through a capacitance, the screen is at approximately the same potential as the cathode as regards r. f. currents. The screen acts as an electrostatic shield between the cathode and the plate. The effect of the screen thus connected is twofold: the grid to plate capacitance of the tube is considerably reduced (see par. 25) and the

amplification factor of the tube is considerably increased. The control grid potential regulates the plate current in much the same manner as in a triode; however, in the screen grid tube the plate potential has very little effect on the plate current. Because of the screening action of the second grid, the same change in plate current which requires a very large change in plate potential is accomplished by a small increment of control grid potential; that is, the amplification factor of the screen grid tube is high. An incidental and generally unwanted effect in tetrodes is the extent of secondary emission, that is, release of electrons from the plate on bombardment by the electrons in the current stream. In a triode these secondary electrons are eventually attracted back to the plate. In a tetrode, however, the positively charged screen competes with the plate for the attraction of these electrons, with the result that when the potential of the plate approaches, or falls below, that of the screen, the screen draws large currents, the plate current is lowered, and the amplification of the tube is reduced.

27. Pentodes and beam tubes.—Pentodes and beam tubes effectively cope with the problem of secondary emission. In the pentode a suppressor grid inserted between the screen grid and the plate, and electrically connected to the cathode, serves to prevent the secondary electrons from moving to the screen grid without otherwise appreciably altering the characteristics of the tetrode. In the beam tube suppression is achieved by a particular design arrangement which provides for a very low intensity electric field midway between the screen grid and the plate. In this region of the low intensity field, electrons are slowed down to such an extent as to accumulate and to present a space charge effect similar to that which surrounds the cathode. The negative charge cloud repels secondary electrons in the same manner as would a suppressor grid. Screen current is minimized in the beam tube by the design of the screen grid, which is such that the constituent wires are in the shadow formed by the control grid of the electron stream from the cathode. The beam tube has a high power sensitivity, that is, high power output for a given signal voltage input.

28. Variable μ tube.—The variable μ tube is a modified tetrode or pentode receiving tube in which the control grid is constructed with some of the grid elements widely separated and others closely spaced. For large negative values of grid bias the closely spaced elements present a high density negative charge to prevent the flow of electrons through them; and the only electrons from the cathode to reach the plate are those passing through the openings between

the widely spaced elements. It is possible by means of an auxiliary rectifier circuit to vary the grid bias of the variable μ tube in accordance with the intensity of the incoming signals and thus to provide automatic volume control to compensate for fading.

29. Multipurpose tubes.—Certain types of receiving tubes have two or more complete sets of elements within one envelope which perform various associated functions. For example, the duplex diode has two cathodes and two plates, and it may be used as a full wave rectifier. The possible combinations are numerous. Some of them will be encountered in section X on radio receivers.

30. Directly and indirectly heated cathodes.—*a.* A cathode which is in the form of a filament directly heated by passing a local current through it has the disadvantage of introducing a ripple in the

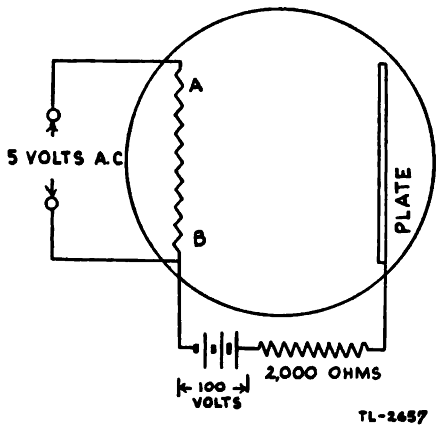
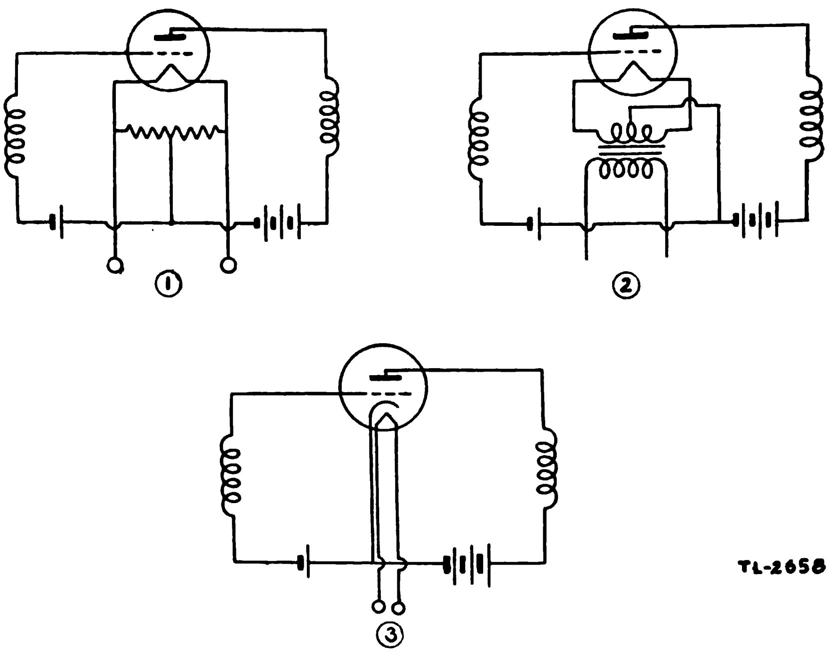


FIGURE 57.—Directly heated cathode.

plate current when alternating current is used for heating. The ripple is most objectionable if the plate and grid returns are made to one end of the filament. In figure 57 the resistor *AB* represents a filament which is heated by applying 5 volts of alternating current across it. For no current flowing through the tube the plate is maintained at a potential of 100 volts above that of point *B*. For a 5-milliampere steady plate current the potential across the tube from *B* to the plate is always $100-2000\times\frac{5}{1000}=90$ volts; whereas the potential from *A* to the plate varies from 85 to 95 volts depending upon the potential of point *A* relative to point *B*, and the total plate current rises and falls at the frequency of the filament current. This condition is remedied to a large extent by connecting the grid and plate

returns to the electrical center of the filament as in figure 58① or ②. But even with a center return arrangement, for a 60-cycle filament current, there is still present 120-cycle modulation of the plate current. This double frequency ripple arises from the effects on the plate current provided by the intermittent rise and fall of the filament temperature, the voltage drop in the filament, and the alternating magnetic field set up by the filament current. Temperature fluctuations in the filament are ordinarily negligible. The latter two effects, how-



① Center-tapped resistor.
② Center-tapped transformer.
③ Indirectly heated cathode.

FIGURE 58.—Methods of utilizing a. c. filament supply.

ever, may be troublesome. The magnetic field about the filament serves to deflect the electrons from their normal paths and so in effect to reduce the plate current. The resulting plate current is largest when the heating current is zero, that is, at intervals which occur at double the heating current frequency. With a voltage drop in the filament, the space current from the negative half of the filament exceeds that from the positive half because of the manner in which space current varies with the electrostatic field across the tube (space current varies as the three-halves power of the plate potential). The result is that

each time the current is a maximum in either direction in the filament, that is, at a frequency which is double the heating current frequency, the space current is increased slightly from the value which obtains during those instants when the current through the filament is zero and the potential of the filament is uniform.

b. In transmitting tubes and in the power stages of a receiver, where the signal currents are large, the double frequency ripple current is neglible in comparison. However, in all other receiver tubes, indirectly heated cathodes (fig. 58③) are necessary wherever a. c. filament operation is desired. An indirectly heated cathode is formed by a metallic sleeve closely surrounding a heated filament and electrically insulated from the filament. The cathode is heated by radiation from the filament. Such an emitter is sometimes referred to as an equipotential cathode, since all parts of it are at the same potential. In general throughout this manual, for simplicity tube heater elements and heater power circuits are not shown in circuit diagrams.

SECTION V

VACUUM TUBE AMPLIFIERS

31. Classification of amplifiers.—Amplifiers are classified according to their general usage as radio or audio frequency amplifiers, and as voltage or power amplifiers; according to the type of coupling between stages as resistance coupled, impedance coupled, or transformer coupled amplifiers; and according to the method of operation as class A, class B, or class C amplifiers. The A, B, and C classifications are based on the following general considerations: class A, high fidelity reproduction; class B, plate circuit rectification; and class C, high efficiency operation.

32. Class A operation.—Class A operation is such that with a single tube in an amplifier stage it is possible to obtain an output plate

current wave shape that is a good replica of the input signal voltage wave shape. This requires that the grid and plate potentials applied to the tube confine the operation to within the substantially straight portion of the i_p–e_g* dynamic characteristic as in figure 59. It is generally desirable to prevent positive swings of grid potential because of the accompanying grid current. A tube which does not draw grid current presents an infinite input resistance. On the other hand. a tube which does draw grid current is equivalent to a shunt resistance

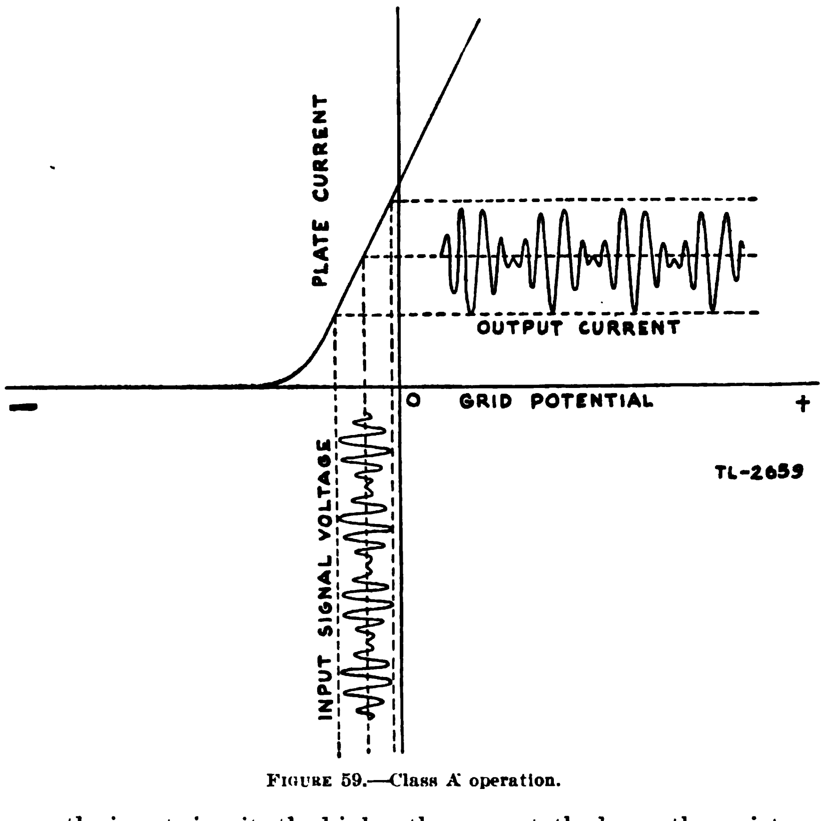


FIGURE 59.—Class A operation.

across the input circuit; the higher the current, the lower the resistance. In r. f. receiver amplifiers, where the grid-to-cathode portion of the tube shunts the preceding tuned circuit, it is in the interest of good selectivity to keep the grid-to-cathode resistance high by operating the tube so as not to draw grid current. A tube which draws grid current suffers distortion of the signal voltage, as indicated in para-

*The subscript g and references to grid, unless otherwise specified, will be taken to indicate control grid.

graph 20, and it requires grid power to excite it. In power amplifiers where economy of grid circuit excitation is generally secondary, distortion of the input wave form with a limited amount of grid current is sometimes tolerated in exchange for the higher plate circuit efficiency—$\frac{\text{a.c. plate power output}}{\text{d.c. plate power input}}$—which results. Negative feedback (par. 42) may be employed to counteract the distortion introduced by the grid current.

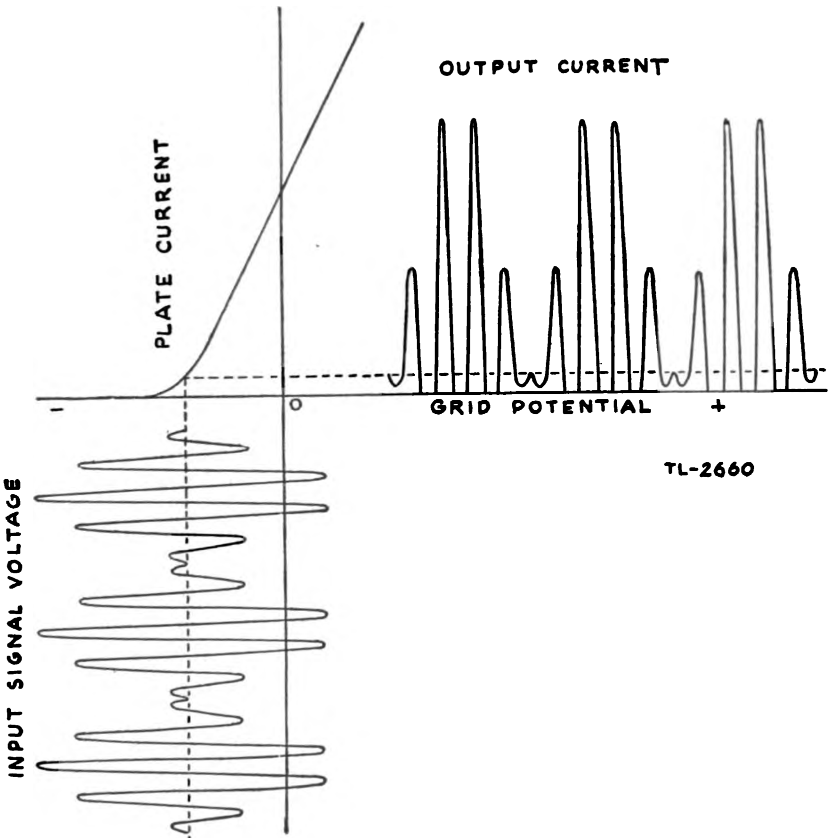


FIGURE 60.—Class B operation.

33. **Class B operation.**—*a.* In a class B amplifier the grid of the tube is biased approximately to cutoff; that is, for no signal voltage the plate current is very small, and with signal voltage impressed the plate current flows essentially only during the positive half cycles of the signal. The signal voltage is allowed to swing sufficiently that operation occurs over the entire linear portion of the characteristic (fig. 60).

The grid usually draws current during part of the time, and the driving source must supply power to overcome the grid losses.

b. For audio frequency class B amplification two tubes are used in push-pull as shown in figure 61. One tube operates during each half of the cycle with a net effect that is comparable in quality to single-tube class A amplification but with much improved plate circuit efficiency.

c. For radio frequency amplification covering a narrow band of frequencies a single tube serves in an amplifier stage (single-ended amplifier) in conjunction with a tuned circuit. The flywheel effect of the tuned circuit (par. 46*a*) supplies the missing half cycles. Distortion present in the single-ended class B radio frequency amplifier is in the form of components of audio frequencies and of radio frequencies.

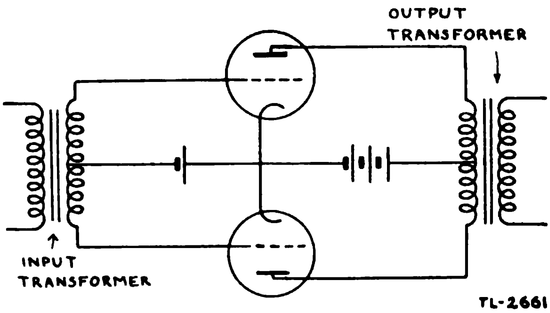


FIGURE 61.—Push-pull amplifier.

The radio frequency components of the distortion are of at least twice the frequency of the input signal, so that all of the unwanted components are conveniently suppressed by the filter action of the tuned circuit, and the output contains only the desired signal amplified. This same filter action is not practicable for a single-ended audio frequency class B amplifier, since here the unwanted distortion frequencies overlap the desired frequencies of the original signal.

d. The output current of a class B amplifier is proportional to the input voltage; thus this type of amplifier is sometimes referred to as a linear amplifier. The class B amplifier is suitable for increasing the output of an amplitude modulated radiotelephone transmitter, the linearity feature preserving the desired wave shape.

e. The plate supply system for a class B amplifier must have good regulation (see par. 77), since the current drawn from the supply varies with the signal amplitude. Further, the driving stage must be of low internal impedance to minimize distortion to the input signal.

34. Class C operation.—A class C amplifier is one which is operated with a negative grid bias which is more than sufficient, under conditions of no signal, to reduce the plate current to zero. The grid voltage usually swings over a wide range, going positive to such an extent as to allow saturation plate current to flow. Distortion is present, even more so than in the class B amplifier, but the flywheel effect and filtering action of a tank circuit make the class C amplifier suitable for developing radio frequency power. The very high efficiency makes it attractive from an economic standpoint. The plate

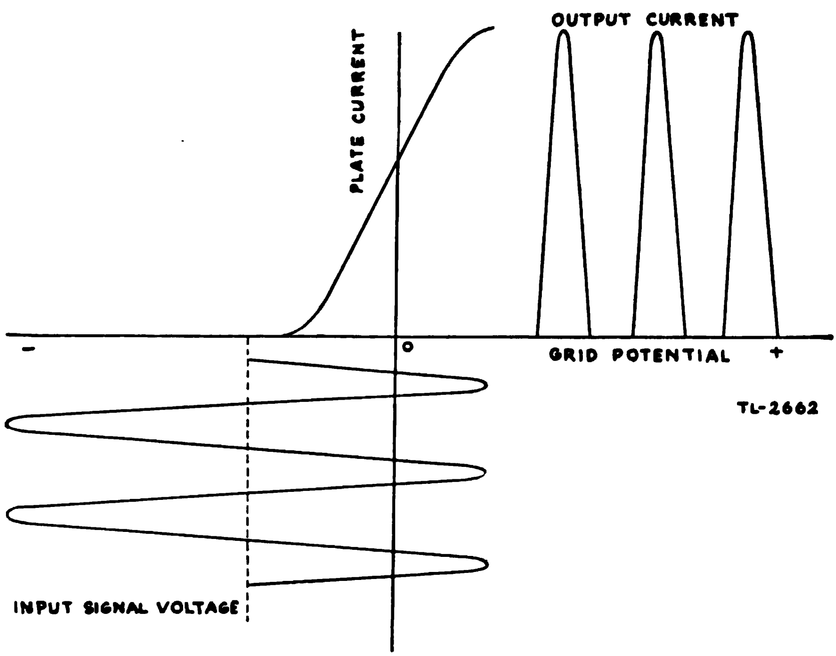
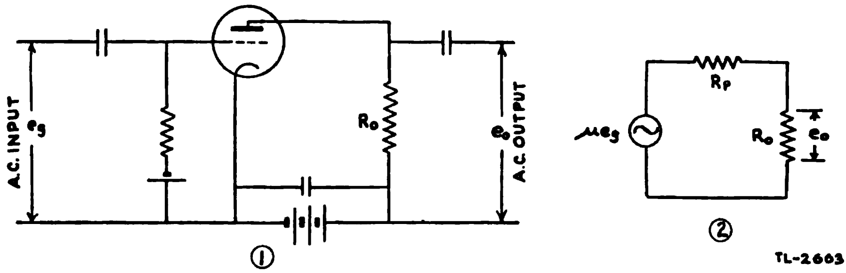


FIGURE 62.—Class C operation.

current of the class C amplifier is proportional to the plate voltage, so that this type of amplifier is ideal for modulation by variation of the applied plate potential. Figure 62 illustrates output current vs. input voltage for a class C amplifier.

35. Voltage gain.—An estimate of the gain to be expected from an amplifier stage may be obtained from a study of an equivalent circuit, that is, a circuit which is basically similar to the actual circuit in electrical characteristics but which is sufficiently simple and explicit to be useful for analysis. The equivalent circuit usually takes into account only the a. c. effects, and ignores, for example, parts

of the circuit relating to power supply. A single stage of a resistance coupled amplifier is shown in figure 63① with its equivalent circuit in figure 63②. Instead of showing the actual input voltage,



① Single stage of resistance coupled amplifier. ② Equivalent circuit.

FIGURE 63.

its effect in the plate circuit is indicated by an a. c. generator labeled μe_g in series with the internal plate-to-cathode resistance of the tube, R_p, and with the load resistance, R_o. If the plate current is i_p, then

$$\mu e_g = i_p R_p + i_p R_o$$

from which

$$e_g = \frac{i_p R_p + i_p R_o}{\mu}$$

The output voltage is

$$e_o = i_p R_o$$

Thus the gain of the amplifier stage is

$$\frac{e_o}{e_g} = \frac{\mu R_o}{R_o + R_p}$$

This shows that for the gain of a resistance coupled amplifier to approach the amplification factor of the tube, R_o must be very large so that R_p is negligible in comparison. However, a practical upper limit to R_o is set by the fact that the potential required to maintain the plate current becomes increasingly large as R_o is increased. The value of R_o is usually compromised on as about the same order of magnitude of R_p.

36. Methods of coupling amplifier stages.—*a.* The resistance coupled amplifier is used extensively for audio frequency applications because of its low cost and relative freedom from distortion. It is occasionally used for certain applications in radio frequency work where an untuned circuit is satisfactory.

b. Figure 64 shows a typical two-stage resistance coupled amplifier. The capacitors C couple the output of each stage to the input of

the following circuit. Each capacitor serves to block the d. c. plate voltage of one tube from the grid of the next, while at the same time permitting ready transfer of the a. c. signal voltages. The function of the resistor R is the same in each stage, in conjunction with the cathode series resistor R_1, to maintain the grid of the tube at the proper bias for class A operation. Normally no current flows through R. Thus the potential drop across R (potential drop= $I \times R$) is zero; that is, the potential of the grid relative to the cathode is entirely determined by the drop in potential occurring with the flow of plate current through R_1. The coupling capacitor C should be large enough to offer a low reactance to the frequencies to be amplified, while the grid leak R should have a very large value so that the shunting effect of the grid leak and coupling capacitor upon the coupling resistor R_o is small. This requirement is manifested by an

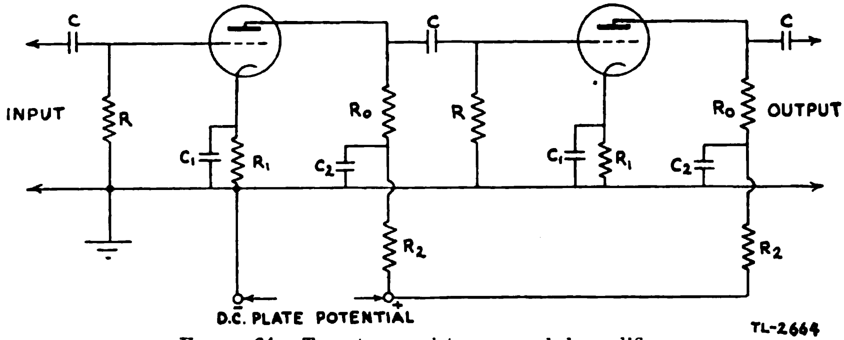


FIGURE 64.—Two-stage resistance coupled amplifier.

examination of figure 65, which is an equivalent circuit of one stage of resistance coupled amplification. It will be recalled from paragraph 35 that the requirement for good voltage gain of the resistance coupled amplifier is a load circuit resistance which is as high as practicable. The capacitors C_1 across the biasing resistors R_1 provide low impedance paths for the a. c. components of plate current, so that grid bias is not varied in accordance with variations in plate current. The reason for the resistors R_2 and capacitors C_2 in the plate circuit of each tube can be seen by a study of the simple circuit of figure 66. The plate current of the second tube, including a. c. and d. c. components, flows through the common plate source. If the plate source contains an internal resistance, the potential across AB fluctuates in accordance with the a. c. output of the second tube. Thus the potential applied to the first tube is modulated by the action of the second tube. This interaction, termed feedback, is

avoided by the use of a decoupling filter—C_2 and R_2 (fig. 64)—in each plate lead which serves to bypass the a. c. components around the plate potential source.

c. The response of the resistance coupled audio frequency amplifier falls off at low frequencies (below roughly 50 cycles) because

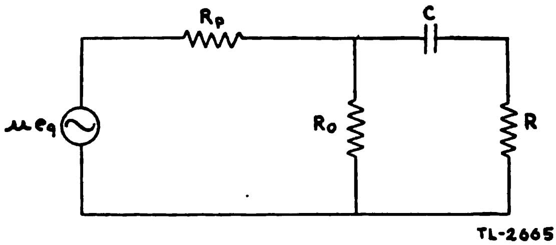


FIGURE 65.—Equivalent circuit of stage of resistance coupled amplifier.

of the high reactance of the coupling capacitors. It falls off at high frequencies (above roughly 5,000 cycles) because of the low reactance of the tubes' interelectrode capacitances, which shunt the load resistors. For intermediate frequencies the response is substantially uniform.

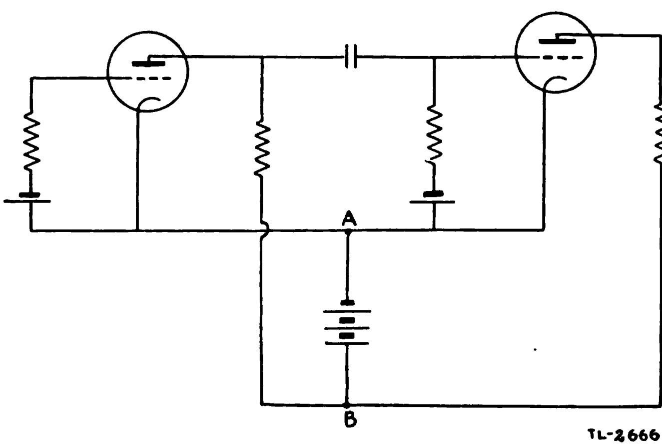


FIGURE 66.—Two-stage amplifier with common plate supply.

d. If large inductors (choke coils) are inserted in place of each plate resistor R_0 in figure 64, an impedance coupled amplifier results. Each inductor offers a high impedance to alternating current, giving a high gain, while at the same time offering low d. c. resistance, thus requiring considerably less supply potential than is needed for the comparable resistance coupled amplifier. The frequency response

characteristic of the impedance coupled amplifier is similar to that of the resistance coupled amplifier.

e. If transformers are used as coupling units between adjacent amplifier stages, the coupling capacitors and grid resistors can be omitted. Figure 67 shows a two-stage transformer coupled amplifier. Transformer coupled amplifiers can be made to give more gain

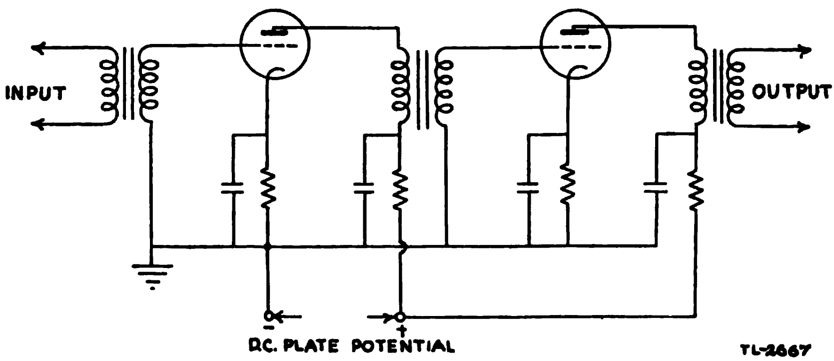


FIGURE 67.—Two-stage transformer coupled audio amplifier.

than either resistance or impedance coupled amplifiers with the use of step-up transformers. The response falls off at the lower frequencies due to the fact that the reactance of the transformer primary decreases with the frequency. At the upper frequencies a decline in response is associated with the effect of the grid cathode capacitance of the following circuit.

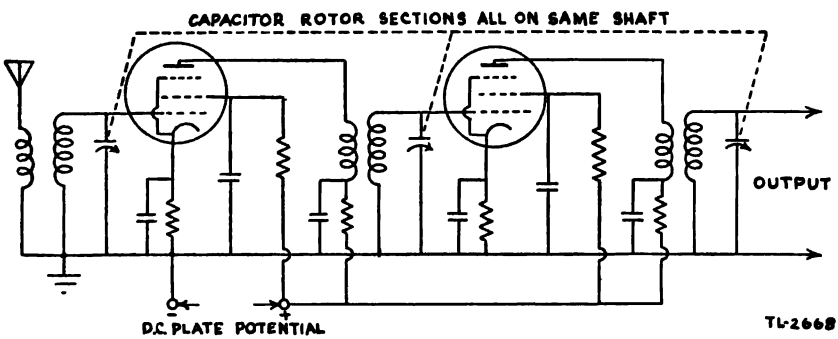


FIGURE 68.—Two-stage r. f. transformer coupled amplifier.

f. An r. f. transformer coupled amplifier employing tuned secondaries and pentode tubes is shown in figure 68. The selectivity (as well as the gain) of such a tuned r. f. amplifier increases with the number of stages in the manner illustrated in figure 69.

37. Bias.—*a.* The choice of a particular type of grid bias depends on the service to which the amplifier is subjected. Most receiver amplifiers use the cathode return resistor bias with shunt capacitor, as in the circuits of figures 64, 67, and 68. Omission of the shunt capacitor, or too small a value of the capacitor, incidentally produces

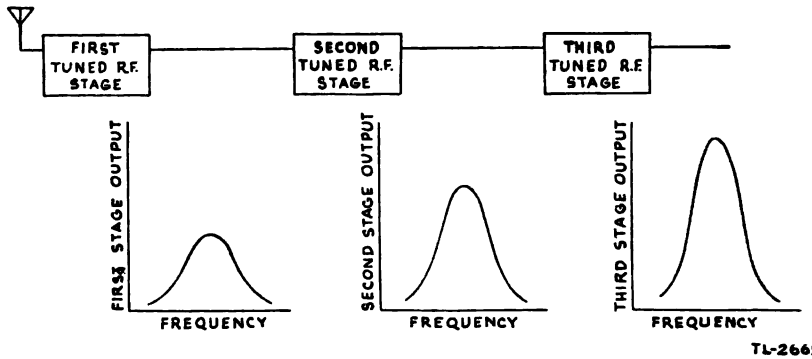
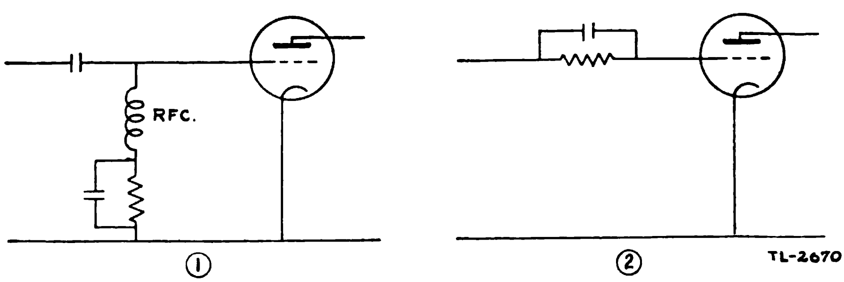


FIGURE 69.—Increase in selectivity with the number of tuned stages in an r. f. amplifier.

degeneration (par. 42) as a result of the variations of grid bias which then accompany the a. c. pulsations of plate current.

b. Grid leak bias (fig. 70) is suitable for use under conditions where grid current flows. This type of bias is economical of power and is thus frequently employed in transmitters. The bias results from the drop in potential across the grid leak (resistor) with the



① Shunt arrangement. ② Series arrangement.

FIGURE 70.—Grid leak bias.

flow of current on positive signal swings. The capacitor across the leak offers a low impedance to a. c., so that the bias is essentially steady in character and is a function of only the magnitude of the grid current. A disadvantage of grid leak bias is that if for any reason the excitation is removed, the bias is removed also, and the

plate current may assume dangerous proportions, causing the liberation of gas from internal parts of the tube or even melting the plate.

c. Batteries, or a separate rectifier filter system distinct from the plate power supply, have the advantage of giving practically constant bias voltage under all conditions of excitation. This type of bias, further, offers protection to an amplifier tube in case of excitation failure. To combine the advantages of grid leak and battery bias, transmitter amplifiers often employ a combination of both types in series. Some amplifier tubes are conveniently designed, as regards bias supply, to operate with the grid at cathode potential (zero bias).

38. Distortion.—*a.* Distortion in an amplifier may be broadly classified under three different headings: Frequency distortion, nonlinear distortion, and delay (or phase) distortion. Frequency distortion arises because of the inability of an amplifier to amplify equally all frequencies. Nonlinear distortion is a consequence of operating over a curved (nonlinear) portion of a tube's characteristic, so that harmonic or multiple frequencies are introduced. Delay distortion results from the effects of transmission of different frequencies at different speeds, giving a relative phase shift over the frequency spectrum in the output. Except at the ultrahigh frequencies or in transmission line work, the effects of delay distortion are usually insignificant. Frequency distortion in r.f. transmitter amplifiers is ordinarily of little concern, since these amplifiers operate over only a relatively narrow range of frequencies at any one time.

b. In r. f. receiver amplifiers, various compensating devices are sometimes employed to provide uniform response to a band of frequencies. Figure 71 illustrates one such compensating arrangement. A high inductance primary winding P, loosely coupled to the secondary S, resonates (due to self-capacitance) at a lower frequency than the lowest for which the amplifier is to operate. This gives high gain at the low end of the band because of the high plate load impedance at the lower frequencies. The small capacitance C, due to a loop of wire hooked around the top of the secondary, provides increased coupling at the higher frequencies to improve the response at the upper end of the band.

c. Distortion which arises from operating a vacuum tube over a nonlinear portion of its characteristic consists principally of multiple frequencies (harmonics) and of sum and difference frequencies corresponding to each frequency present in the original signal. Suppose, for instance, that the input signal to a nonlinear radio frequency amplifier is composed of three frequencies: 500,000, 501,000 and 501,025

cycles. The output then contains in addition to the three original frequencies mainly the following distortion frequencies:

(1) Harmonics: 1,000,000, 1,500,000
1,002,000, 1,503,000
1,002,050, 1,006,075

(2) Sum frequencies: 1,001,000, 1,001,025, 1,002,025

(3) Difference frequencies: 1,000,25, 1,025.

The filtering action of a parallel resonant circuit in an amplifier plate circuit which is tuned to about 500,000 cycles minimizes the effects of all these distortion components. The extent of this suppression of the distortion frequency components may be controlled by proper design of the tuned circuit. At frequencies well off resonance the parallel circuit offers essentially the impedance of the lowest im-

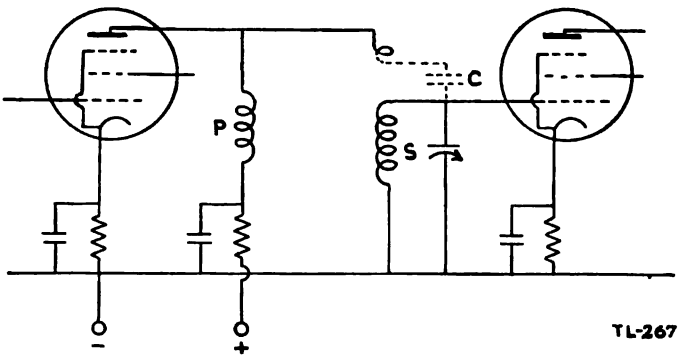


FIGURE 71.—Special circuit arrangement in r. f. amplifier to provide uniform response over a band of frequencies.

pedance branch. In a circuit tuned to 500,000 cycles the impedance offered to currents of frequency 1,000,000 cycles is practically that of the capacitor alone, and the impedance offered to currents of frequency 1,000 cycles is practically that of the inductor alone. Thus a low *L*-to-*C* ratio minimizes the voltages developed across the parallel circuit at the distortion frequencies. Two tuned circuits between which it is desired to transfer energy sometimes employ link coupling as shown in figure 72. In this manner incidental coupling between the two circuits due to the distributed capacitance of the turns is avoided, and the transfer of harmonics from one circuit to the other is avoided.

d. In an audio frequency amplifier the distortion frequencies corresponding to *c*(1), (2), and (3) above generally overlap components of the desired signal frequencies, so that filtering is not feasible. In the audio frequency case the problem demands prevention rather than

cure. Class A operation is one solution. Push-pull arrangements are of further assistance.

e. Of the harmonic frequencies, the second (first overtone) is usually the predominant one. The rest are ordinarily weak. It is the objectionable second harmonic (as well as all other even order

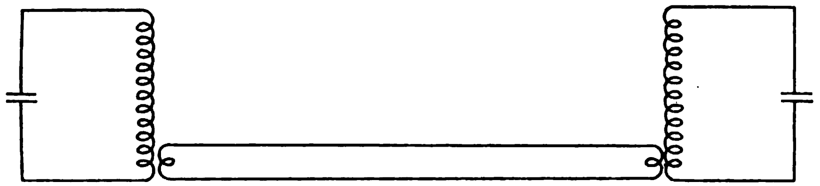


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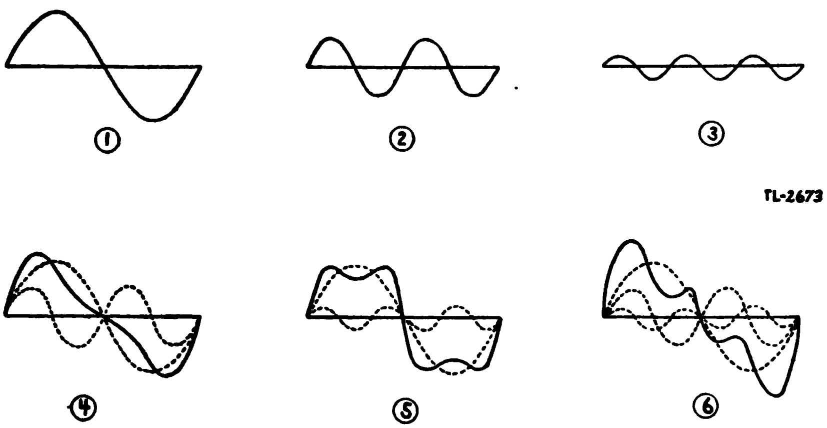
FIGURE 72.—Link coupled tuned circuits.

harmonics) which is absent in the output of a push-pull amplifier. By way of analysis to see that such is the case, consider the curves of figure 73. Here ① represents a fundamental signal frequency (first harmonic); ② and ③ are multiple frequency curves, second and third harmonics of the signal, respectively. The solid curve



① Fundamental.
② Second harmonic.
③ Third harmonic.
④ Fundamental plus second harmonic.
⑤ Fundamental plus third harmonic.
⑥ Fundamental plus second and third harmonics.

FIGURE 73.—Harmonic distortion.

of ④ is obtained by adding the fundamental ① and the second harmonic ②. The solid curve of ⑤ is obtained by adding the fundamental ① and the third harmonic ③. Fundamental, second harmonic, and third harmonic are compounded to yield the solid curve of ⑥. The resultant in ⑤ is such that if the negative half cycle of

the curve is shifted along the abscissa (horizontal axis) so as to be directly below the positive half cycle, the negative half cycle then presents a mirror image of the positive half cycle about the abscissa. It can be shown that any combination of odd-order harmonics possesses this same symmetry; further that any resultant wave formed by a combination of harmonics and which possesses this symmetry cannot contain any even-order harmonic elements. In push-pull action two tubes interchange roles during alternate half cycles such that if the dashed curve of figure 74 represents the output of one tube, the dotted curve of the same figure represents the output of the companion tube. Dissymmetry in the output wave form of each individual tube indicates definite even-order harmonic content; whereas symmetry of the combined wave form shows complete absence of any even-order harmonics.

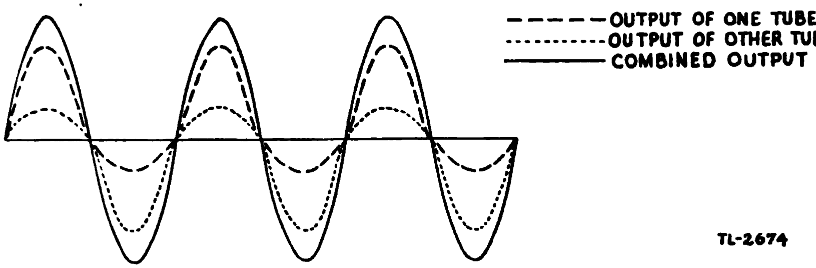


FIGURE 74.—Wave forms in push-pull amplifier.

f. Push-pull operation serves to lessen distortion in other ways. (1) The direct currents present in the two halves of the output transformer primary balance each other in their magnetic effects, so that the core cannot become d. c. saturated. (Saturation is a state of magnetization of the core which obtains for reasonably large currents and such that further increase in current produces only a small increase in magnetic induction.)

(2) Alternating current components of plate supply potential which are due to incomplete filtering produce no effect in the output transformer secondary, since the potentials thus developed across the primary balance each other. Because of the difficulty of obtaining perfect balance, particularly in tubes, the full possibilities of push-pull amplifiers are seldom realized in practice. However, under conditions of moderately good balance, the push-pull amplifier offers a definite improvement in quality over a comparable single-ended amplifier.

g. For doubling the frequency at radio frequencies in a transmitter, with a single-ended amplifier operating into an appropriately tuned

LC circuit, harmonic distortion within the tube is deliberately encouraged.

39. Maximum power transfer.—One basic consideration in the design of amplifiers, or in any radio circuit design, is that of maximum power transfer from a generator into its load, for example, from a vacuum tube into its plate load impedance. A general rule to follow in this respect is that maximum power transfer is effected between a generator and its load when the resistance of the load equals the internal resistance of the generator. The condition of maximum power transfer is not necessarily that of maximum undistorted power transfer nor that of maximum efficiency. However, maximum power transfer, which in many cases is the only function of impedance matching, is frequently chosen as a working criterion.

40. Feedback.—Feedback, the introduction of energy from the plate circuit back into the grid circuit, in an amplifier may occur unintentionally, and so uncontrollably, as with the use of impedances common to two or more stages. Feedback of this nature may or may not adversely affect the amplifier characteristics, but is usually avoided as a precautionary measure. Controlled feedback, on the other hand, may materially improve an amplifier's operation. The feedback is from the output of one stage to the input of the same or of a preceding stage, and may be in the same phase as that of the signal which it supplements (regeneration) or in opposite phase (degeneration). In regeneration a fraction, possibly one percent, of the output is reintroduced into the input, with an over-all increase in the amplification of the stage. In degeneration a fraction of the output is reintroduced in reverse phase. A high gain amplifier can suffer a certain amount of loss of gain due to degeneration and still present a high voltage amplification. The advantage of regeneration is an increase of amplification. The advantage of degeneration is an improvement in quality. Design problems in either case—to obtain exact in-phase or exact out-of-phase feedback relations—are sufficiently involved to warrant simple straight amplification for most amplifiers. The elimination of unwanted feedback is accomplished by introducing compensating voltages in opposite phase (neutralizing) or by preventing the inception of feedback by careful shielding and by the use of such devices as screen grid tubes (with low interelectrode capacitance) and decoupling filters. The magnitude of the feedback can be controlled by regulating the amount of coupling between the output and input circuits. The degenerative feedback voltage is always less than the signal voltage and can never equal the signal voltage. Any attempt to increase the magnitude of the feedback in the hopes of approaching

the magnitude of the signal results in a decrease of the difference voltage, which is that applied to the input of the amplifier. Equal signal and feedback would correspond to zero impressed voltage and consequently to zero output. On the other hand, regenerative feedback voltage can, and usually does, exceed the signal voltage.

41. Regeneration.—*a.* To appreciate the manner in which the magnitude of the feedback is controlled by the coupling, consider a practical example of regeneration. Take the following values for the constants of the circuit of figure 75:

Frequency of the signal	1000 kilocycles
Q of the tuned circuit	200 at 1000 kilocycles
Transconductance of the tube	0.0006 mhos
M (mutual inductance)	$\frac{8}{2\pi}$ microhenrys

The particular figure of $\frac{8}{2\pi}$, approximately 1.27, is chosen for the value of M since it simplifies the computations.

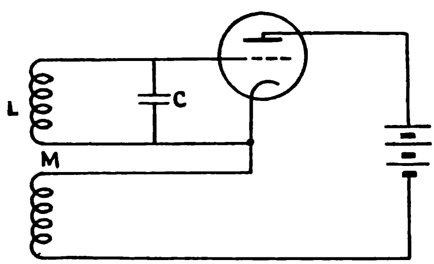


FIGURE 75.—Feedback amplifier.

b. Suppose a signal of 1 microvolt is induced in L from the preceding circuit (not shown). Then Q times 1, or 200 microvolts, is the corresponding input voltage to the tube. This voltage causes a change of current in the plate circuit equal to the product of the voltage on the grid and the transconductance of the tube: $200\times 0.0006=0.12$ microampere. This plate current, in turn, induces a voltage in L equal to the product of the plate current and the mutual reactance ($2\pi fM$) of the coupled circuits: $0.12\times 2\pi\times 1000\times 8/2\pi=0.96$ microvolt. If the relationships between the windings are such that this voltage adds to that which was induced in L by the original signal, then the net effective impressed voltage in the LC circuit is $1+0.96=1.96$ microvolts. Computations for the continued process are illustrated in part in table II. The increases in voltage and

currents become less with each transfer of energy from the plate to the grid circuit, until, under these particular circumstances, the voltage input to the tuned circuit ultimately becomes and remains 25 microvolts. The complete process occurs almost instantaneously.

TABLE II

Net voltage induced in the tuned circuit (microvolts)	Voltage across capacitor C (microvolts)	Radio frequency plate current (microamperes)	Voltage induced in the tuned circuit by the radio frequency plate current (microvolts)
1.00	200	0.120	0.96
1.96	392	0.235	1.88
2.88	576	0.346	2.77
3.77	753	0.452	3.62
4.62	923	0.554	4.43
5.43			

c. The 25-fold magnification produced by the regeneration might equally well have been produced by a reduction of the tuned circuit resistance to $\frac{1}{25}$ of its original value. Thus the regeneration has the effect of a "negative" resistance in the tuned circuit, the value of which is $\frac{24}{25}$ the actual tuned circuit resistance, and the selectivity and sensitivity of the tuned circuit are increased accordingly.

d. It is to be observed that if, at any time, the original impressed signal is removed, the output is accordingly reduced to zero. This may be seen from table III, which tabulates the results of removing the signal voltage. Only the net input and feedback voltages are herein recorded, since the intermediate steps are not essential to the discussion.

TABLE III

Net input (microvolts)	Feedback (microvolts)
25.0	24.0
23.1	22.2
21.3	20.4
19.6	18.8
18.1	17.4
16.7	

e. Less than a 25-time amplification could have been had by reducing the mutual inductance, that is, by reducing the coupling between the output and the input circuits. To study the effects in the case where the coupling is increased to such an extent that the voltage fed back each time exceeds the corresponding net input voltage, con-

sider a situation where M has a value of $\frac{10}{2\pi}$, or approximately 1.59, microhenrys. Corresponding input and feedback voltages for this case are given in part in table IV.

TABLE IV

Net input (microvolts)	Feedback (microvolts)
1. 00	1. 20
2. 20	2. 64
3. 64	4. 34
5. 34	6. 40
7. 40	8. 88
9. 88	

f. It will be noted that the difference between succeeding input voltages increases each time, so that as long as power is available to supply the circuit requirements, the amplification increases indefinitely. Moreover, the original signal no longer exercises control, and the output continues even if the original signal is suppressed. An amplifier in this condition may be made to serve a useful purpose, as a generator, however, rather than as an ordinary amplifier. The functioning of an amplifier in this capacity is described in detail in section VI. For a treatment of the general case of regeneration, see appendix I.

g. The results of this analysis, although illustrated for a radio frequency amplifier, apply with only minor modifications to audio frequency amplifiers.

42. Degeneration.—*a*. The increased quality secured with degeneration is twofold: the amplification is more nearly independent of variations of circuit constants (independent, for example, of variation of impedance of a loud speaker with frequency) and distortion which is not present in the input signal, but which arises from within the amplifier, is reduced. Degeneration finds particular application in audio frequency circuits, and in audio-frequency-modulated r. f. circuits, where fidelity of reproduction is important.

b. The first feature of degeneration noted above is apparent from a simple analysis. Take the input signal to a degenerative amplifier as e and the output as E. If B is the fraction of the output fed back, the degenerative feedback voltage is BE. Then the net input voltage is $e-BE$, and the output is

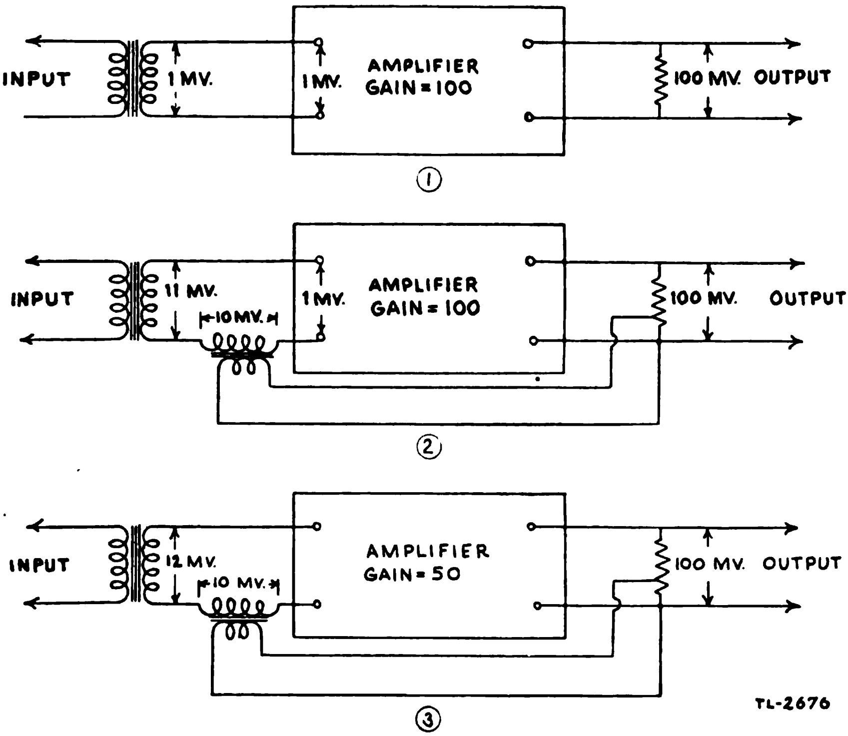
$$E=A\times(e-BE)$$

where A is the normal gain of the amplifier; so that the over-all gain is

$$A_o=\frac{E}{e}=\frac{A}{1+AB}$$

This shows that the gain of the amplifier with degeneration is less than the normal gain without any feedback. Further, for the case of B large enough such that AB is much greater than 1 (perhaps 25 in an amplifier with a normal gain of 100) the over-all gain becomes approximately

$$A_o=\frac{A}{AB}=\frac{1}{B}$$

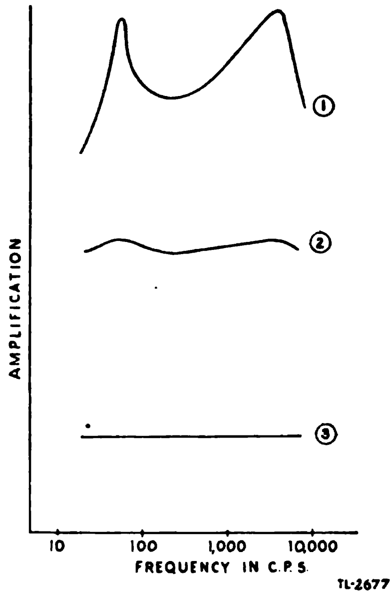


① No feedback.
② and ③ Ten percent degenerative feedback.

FIGURE 76.—Effect of degeneration.

that is, the over-all gain is substantially independent of the normal gain of the amplifier. For a specific example to illustrate this effect, consider an amplifier which without any feedback has a normal gain of 100. An input of 1 millivolt gives rise to an output of 100 millivolts (fig. 76①). Suppose degenerative coupling is now provided

such that 10 percent of the output is returned to the input. If the output under these circumstances is 100 millivolts, 10 millivolts will be introduced into the input of the amplifier in reversed phase from the signal. In order for the output to remain 100 millivolts, it is necessary that a net input of 1 millivolt in phase with the signal be maintained. A signal of 11 millivolts is necessary to maintain this 1 millivolt net input: 11 millivolt signal − 10 millivolt feedback = 1 millivolt input (fig. 76②). It should be noted how under conditions of degeneration the over-all amplification is considerably re-



① Straight amplification.
② Same amplifier with degeneration.
③ Same amplifier with increased degeneration.

FIGURE 77.—Response characteristic of amplifier with loudspeaker load.

duced. Without degeneration the over-all gain is 100 to 1. With degeneration the over-all gain is now 100 to 11. Suppose now that under some particular circumstances, possibly for some particular frequency range, the normal gain of the amplifier is reduced to 50. It would then require a 2 millivolt net input to give an output of 100 millivolts. For 10 percent degeneration this means a 12 millivolt signal: 12 millivolt signal − 10 millivolt feedback = 2 millivolt input (fig. 76③). The over-all amplifier gain is now 100 to 12. Thus only a very small percentage reduction in over-all amplification, from $^{100}/_{11}$ to $^{100}/_{12}$ results from a 50 percent reduction in the normal

amplifier gain. Actual experimental curves showing response characteristics corresponding to straight operation and to degeneration for the same receiver amplifier with a loudspeaker load are shown in figure 77. The independence of amplifier gain with frequency means an improvement in the quality of the amplifier reproduction. Whereas the amplifier normally might discriminate against certain frequencies and accentuate others, with degeneration all the desired frequencies are amplified nearly uniformly.

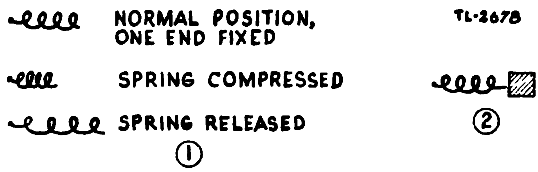
c. The second feature of degeneration—reduction of noise produced within the amplifier—depends on the fact that the signal, which is introduced in the grid circuit of the amplifier, receives greater relative magnification than those particular noises which are introduced in the plate circuit. The grid signal is amplified, whereas the plate noise is not; while that portion of the output which is returned out-of-phase to the input is amplified equally for both noise and signal components. The reamplification of this out-of-phase signal component reduces the amplifier gain; the reamplification of the out-of-phase noise component effectively reduces the noise current present. Hence, the cancellation effect of the degeneration combined with the differential effect of straight amplification results in a relative reduction of the noise produced within the tube, at the price of a general reduction in gain. If the feedback can be made into a preceding amplifier stage, where it is presumed that no distortion of the same type occurs, then the degeneration could be controlled so that the output of the first stage consists of the desired signal, and a distortion component sufficient to counterbalance the noise present in the output of the last stage, while at the same time the over-all gain of the two stages is reduced only slightly.

Section VI

VACUUM TUBE OSCILLATORS

43. Mechanical oscillations.—Two fundamental requirements of any type of natural oscillation are an inertial element and a restoring force. Consider a coil spring lying horizontally on a table with one end of the spring clamped, as in figure 78①. If a force is applied

to the free end so as to compress the spring and then the compressing force is removed, the energy stored in the spring on compression is released to extend the spring back to its normal length. More than likely the spring may actually distend a small amount beyond its normal length and then compress again slightly; that is, the spring may alternately expand and contract so that the free end oscillates a few times about its equilibrium position before coming to rest. What causes the spring to continue beyond its normal length is described as the inertia of the spring and is attributed to its inherent



① Oscillations of a coil spring.
② Spring with mass attached to free end.

FIGURE 78.

mass. If a large concentrated mass is attached to the end of the spring (fig. 78②), the tendency for the spring to continue past its equilibrium position is more pronounced. Also the period of oscillation, the time for one complete to-and-fro motion, is lengthened. The period is longer for a weaker spring, that is, for one with a weaker restoring force; and it is shorter for a stronger spring.

44. Electrical oscillations.—Electrical counterparts of the mass and spring are an inductor and a capacitor, furnishing inertia and restoring force, respectively, for electronic transfer. If by some

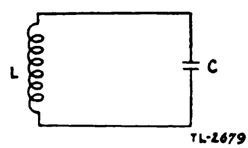


FIGURE 79.—Oscillatory circuit.

electrical force a separation of charge within the ideal (no resistance) closed circuit of figure 79 is made to occur such that some electrons are taken from the lower plate of the capacitor and transferred to the upper plate, a certain amount of energy is stored in the capacitor in the process. On removal of the electric force the energy stored in the capacitor is free to transfer the electrons back to the lower plate. As the electrons in question are released, their flow through the inductor sets up a magnetic field about it, and this magnetic field, once es-

tablished, tends to prevent any decrease in the flow of electrons which might be expected after the original charge distribution is reestablished. As a matter of fact, the energy in the electrostatic field of the capacitor is transferred to the magnetic field of the inductor with the flow of charge; and at the instant of resumption of the original charge distribution the total energy of the circuit is associated with the magnetic field. The energy in the magnetic field is now available to transfer even more electrons from the upper plate to the lower, until the energy of the magnetic field is entirely diverted back to the electrostatic field. These energy relations are similar to those in the mechanical example. In the latter situation energy originally stored in the spring is released on removal of the compressing force with an ensuing transfer of energy from potential form in the spring to kinetic form in the mass until, at the instant the spring is expanded to its normal length, the energy—except for heat losses—is completely associated with the motion of the mass. This energy of motion carries the mass past its equilibrium position; and when the mass finally comes to momentary rest at the end of its swing, the energy of its motion has entirely disappeared, and energy is now present as potential energy in the extended spring, ready to send the poised mass in the opposite direction toward its equilibrium position again. At this point in the electrical case the capacitor is recharged exactly to its original magnitude but in opposite polarity, and the discharge proceeds in the opposite direction. The rate of charge and discharge which follows can be controlled by varying the capacitance or inductance, or both, just as the spring vibration frequency is controlled by varying the spring tension and/or the mass. The alternate charge and discharge of the capacitor does not continue indefinitely in an actual circuit, but damps out after a brief interval in the same manner as does the spring-mass combination, and for the same reason, that is, resistance. If the friction between the spring-mass and the table is reduced, perhaps by using a glass table top, the duration of the oscillatory motion is prolonged. If all the friction in the system could conceivably be removed, the oscillations should continue indefinitely. In the electrical circuit resistance develops from the collision of the electrons of the current stream with the constituent entities of the conductor traversed. The energy shared in this manner is ultimately all converted into heat, manifesting itself by a rise in temperature of the conductor and of the surroundings, and being lost for all practical purposes. If the inherent resistance of the oscillatory circuit could be reduced to a small magnitude, just the small amount of energy necessary to replenish

that lost in the form of heat on each cycle could probably be delivered periodically in escapement wheel fashion from an external source to sustain the oscillations in the *LC* circuit indefinitely. This is precisely what occurs in a vacuum tube oscillator. The tube and the associated circuit equipment serve as an escapement mechanism to trigger off energy from the power supply at appropriate intervals.

45. Simple oscillator circuit.—A simple scheme to achieve this end is illustrated in figure 80. The voltage across the capacitor *C* of the oscillatory circuit is applied to the grid of a vacuum tube so that variations in the vacuum tube output current correspond exactly with variations of the capacitor potential. This circuit is exactly the same as that employed previously to obtain regenerative amplification of an impressed signal whose frequency was that of the natural frequency of the tuned circuit $\left(f=\frac{1}{2\pi\sqrt{LC}}\right)$ In the regenerative case the feedback was definitely restricted so

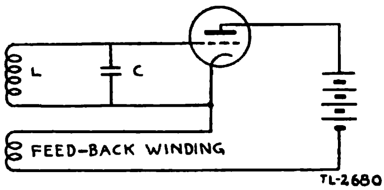


FIGURE 80.—Simple vacuum tube oscillator circuit.

that the presence of the input signal was essential; that is, the signal served to control the frequency, and amplification followed accordingly. Here the feedback voltage is sufficiently large that the signal voltage is unnecessary (once the action is started); and sustained currents are obtained at a frequency which is controlled only by the natural frequency of the tuned *LC* circuit.

46. Practical oscillator circuit.—*a.* Intermittent feedback impulses as supplied by a class C amplifier are quite adequate for sustaining the oscillations and are more economical of power than is the continuous feedback obtained with a class A amplifier, since with the former there is a smaller proportion of power loss within the tube itself. An arrangement to provide intermittent feedback impulses is shown in figure 81. Here the grid is biased by the voltage developed across the resistor *R* in accordance with the grid current, which in turn is determined by the magnitude (not frequency) of the potential of the capacitor. (See par. 37.) After oscillations are once established, a fixed battery bias to maintain the class C operation would serve. However, to permit self-starting of

the oscillations, the bias must be such that some plate current flows initially, since it is the first pulse of plate current that contributes the necessary pulse of potential across the LC circuit to set off the oscillatory action. Grid leak bias regulates itself to the requirements ideally. Figure 82 depicts the manner in which grid potential e_g,

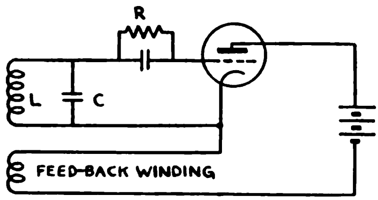


FIGURE 81.—Simple oscillator with grid leak bias.

grid current i_g, and plate current i_p vary as oscillations are initially built up. The persistence of oscillations in the LC resonant circuit with only intermittent pulses being released by the tube is commonly referred to as the circuit *flywheel effect.*

b. During the build-up of the oscillations, as the amplitudes of the oscillatory current and of the grid and plate currents increase,

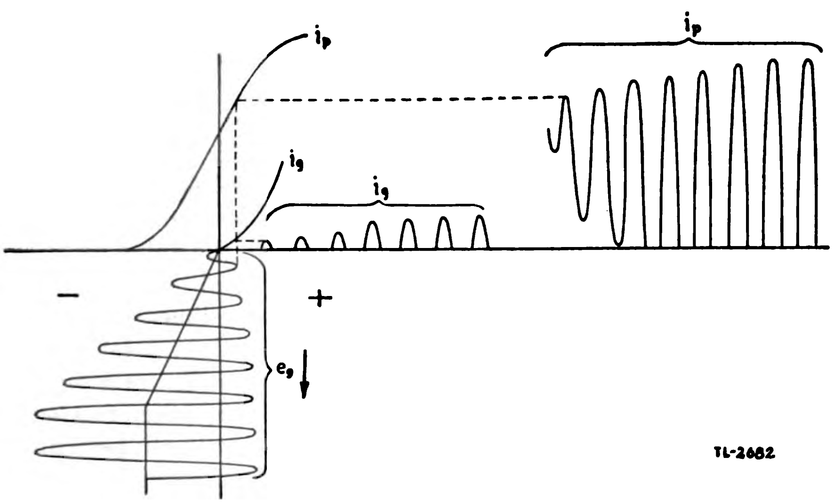


FIGURE 82.—Build-up of oscillations in grid leak bias oscillator.

the accompanying losses increase (and in proportion to current squared). If the direct current source is able to furnish only a limited amount of power, the magnitude of the oscillations is determined by the power available. Otherwise the amplitude of the

oscillations increases until the operation extends to the knee of the tube's i_p–e_g characteristic, where the transconductance falls off and with it the output of the amplifier, too. This results in a decreased feedback and so a decreased grid swing, with a consequent increase in the transconductance which affects the peaks of the swing. In this way any tendency for the oscillations to assume a magnitude above or below a certain critical value is counteracted with an opposing effect by the instantaneous transconductance, which acts to keep the level of the oscillations uniform.

c. The frequency of oscillation is given to a good approximation by

$$f=\frac{1}{2\pi}\sqrt{\frac{1+R/R_p}{LC}}$$

where R_p is the internal plate to cathode resistance of the tube; and R is the resistance of the LC circuit, including that resistance which is effectively introduced into the tank circuit when a load is coupled into the tank circuit to draw power from it. Variations in R_p occur with any slight changes in the vacuum tube electrode potentials. R/R_p is usually very much less than 1, so these changes produce only small, probably one part in 10,000, shifts in frequency. Nevertheless, demands on frequency stability are sufficiently exacting to warrant such design as will minimize the effects of plate resistance variation. The equation above suggests the use of the smallest possible value of R and the largest possible value of R_p which are consistent with other factors for good operation. A low R is the result of a low inherent resistance in the tank circuit together with a small load. The load might be the input to a sufficiently biased intermediate amplifier, but it should not be a radiating system, for example. For a particular frequency (which fixes the product LC) and for a given Q, the value of R can be reduced and stability encouraged by using a small L (low L to C ratio); the smaller the inductance, the smaller the dimensions of the coil, and the lower the inherent resistance. Further, a large C in itself is an effective aid to stability because small variations in capacitance due to mechanical vibration or to the presence of external bodies (hand capacitance) produce only a low over-all percentage change in the capacitance of the resonant circuit.

47. Oscillator circuits in general use.—*a.* A number of variations of oscillator circuit design are shown in figure 83. All of them are fundamentally alike, differing principally in the disposition and in the manner of coupling of elements. The feedback in the tuned-plate tuned-grid circuits is through the plate-to-grid capacitance within the tube.

b. An oscillator circuit is usually required merely to control the frequency and not to deliver any appreciable amounts of power. Power is developed by amplification in the succeeding circuits, where load changes have a much smaller effect on frequency. The electron coupled oscillator combines the functions of oscillator and power amplifier with one tube. The cathode, control grid, and screen grid of the tube serve as a triode oscillator. The coupling between the oscillator and

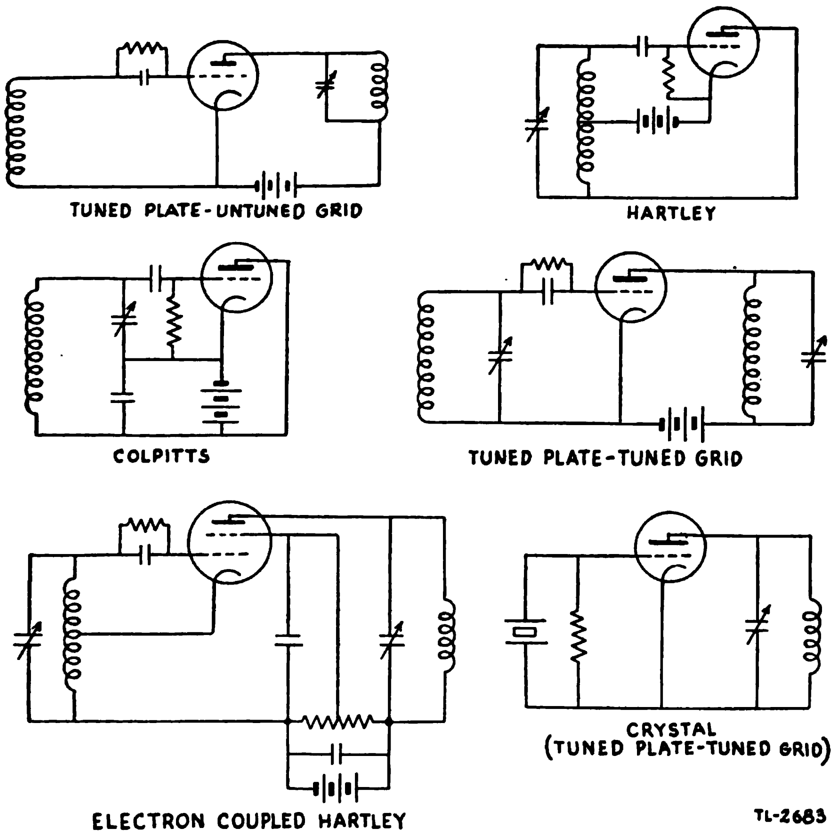


FIGURE 83.—Basic oscillator circuits.

amplifier circuits is through the electron stream. Capacitive coupling is reduced to a minimum by operating the screen at ground potential as far as r. f. currents are concerned. This effectively isolates the output from the input circuit, so that the frequency of oscillation is relatively independent of load variations. Further, an increase of plate potential causes a frequency shift in one direction, whereas an increase in screen potential causes a frequency shift in the opposite direction.

By properly adjusting the screen tap on the voltage divider, the frequency may be made independent of any variations in the plate supply.

c. The crystal oscillator provides a remarkably steady frequency output. The oscillator proper is a crystal of quartz, which exhibits the property of developing an electrical potential across its faces when mechanically strained, and vice versa, expanding or contracting on the application of a potential. At the natural period of the mechanical vibrations of the crystal the two actions may be made mutually self-sustaining by feeding back a sufficient portion of the amplified potential to replenish the energy which is dissipated during each cycle as heat. The equivalent electrical circuit of the crystal, shown in figure 84, has a very high Q and a very high L to C ratio. C_1 in figure 84 represents the capacitance which exists between the mounting

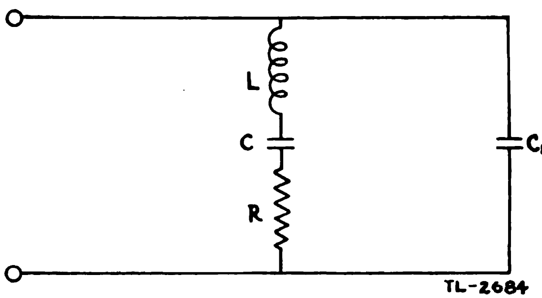


FIGURE 84.—Equivalent electrical circuit of oscillating crystal.

electrodes. L, C, and R represent the electrical equivalents associated with the vibrational characteristics of the crystal. At frequencies above that which corresponds to series resonance in LCR, LCR behaves as an inductance. This inductance and C_1 form a parallel tuned circuit, the antiresonant frequency of which is the frequency of the sustained oscillations. Since C is in general very much smaller than C_1, the series resonant frequency and the antiresonant frequency of the crystal lie very close to each other.

48. Oscillators for very high frequencies.—*a.* Resonant circuits for very high frequency oscillators sometimes take the form of short wires joining cathode and plate, with the necessary capacitance being furnished by that existing between electrodes within the tube itself. In other instances a pair of parallel wires (transmission line), short-circuited at the far end, is employed as a resonant circuit. A quarter-wave-length line (par. 85*c*) exhibits the properties of a high Q parallel resonant circuit.

b. At the ultrahigh frequencies, 50 megacycles and above, mechanical problems are encountered in the reduced sizes of the tube and cir-

cuit elements, while electrical difficulties arise in the form of frequency instability and decreased efficiency. Several forms of electron oscillator have been developed tc replace the conventional vacuum tube at the ultrahigh frequencies.

Section VII

CONTINUOUS WAVE TRANSMITTERS

49. Oscillator-amplifier transmitter.—*a.* A simple oscillator-amplifier combination for transmitting is shown in figure 85. The r. f. choke RFC_1 and the capacitor C_1 act as a filter to by pass radio frequency current around the oscillator plate supply. Because of the

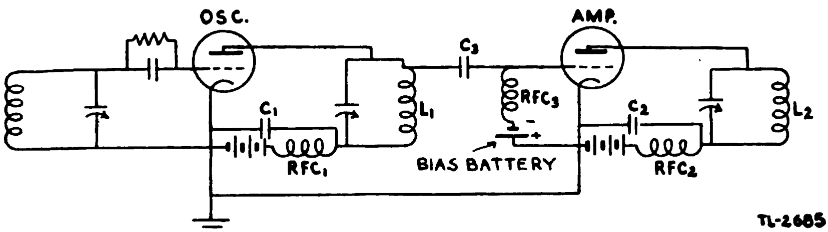


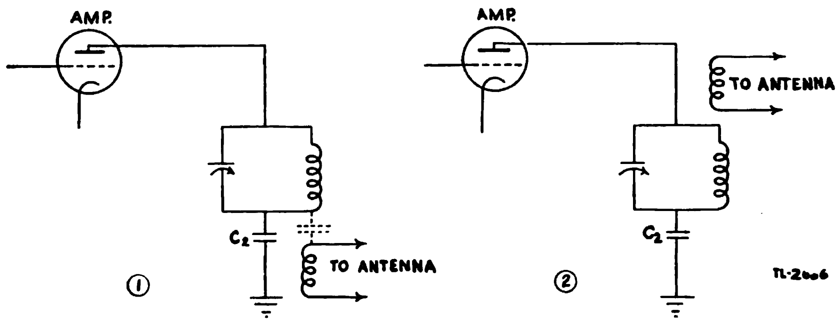
FIGURE 85.—Oscillator-amplifier transmitter.

low r. f. impedance of C_1 there is no appreciable r. f. voltage drop across this capacitor, and the lower end of the oscillating tank circuit is practically at ground potential as regards r. f. voltage. Capacitor C_3 blocks the oscillator d. c. plate voltage from the grid of the amplifier, while at the same time offering a low impedance path for radio frequency current. The r. f. choke, RFC_3, in series with the amplifier bias battery, is necessary to maintain a high impressed r. f. voltage on the amplifier grid. Capacitor C_2 and r. f. choke coil RFC_2 serve to direct r. f. currents around the amplifier plate supply.

b. If the amplifier is to be coupled into an antenna, the arrangement of figure 86① is preferable to that of figure 86②. In either case energy can be coupled through the inherent capacitance existing between the two coils. Such energy transfer must include some harmonic component because of the low impedance offered to high frequencies by this capacitance. However, in ① the electric field

across the inherent capacitance (indicated by dotted lines) is negligible, since the lower end of the amplifier tank coil is approximately at ground potential by virtue of C_2. As a consequence the coupling in ① is almost entirely magnetic, and harmonic transfer is held to a minimum; whereas in ② the coupling has a greater capacitive component, hence a greater harmonic transfer.

50. Neutralization.—*a.* The radio frequency plate and grid circuits of the amplifier of figure 85 form a tuned plate-tuned grid oscillator; and unless some action is taken to prevent it, the amplifier will self-oscillate. One function of the amplifier is to isolate the oscillator from the ultimate load, the radiating system, in the interest of stability. An oscillating amplifier fails to serve this end. Only



① Correct method. ② Incorrect method.

FIGURE 86.—Coupling amplifier tank coil to antenna.

when the amplifier operates as a nonoscillating amplifier is the frequency relatively independent of any variations of its plate load impedance.

b. A favorite technique for suppressing oscillation within an amplifier consists of neutralization, that is, the introduction of a feedback voltage from the plate to the grid circuit which is equal in magnitude and opposite in phase to that which occurs as a result of the plate-to-grid capacitance within the tube. Figure 87 shows such a neutralizing arrangement adapted to the amplifier of figure 85. In figure 87, the amplifier tube interelectrode capacitance is indicated by dotted lines. Neutralization is accomplished by operating the oscillator normally and removing the plate potential to the amplifier stage. C_N is adjusted until a minimum reading is obtained on an r. f. milliammeter coupled to the tank coil, L_2, of the amplifier stage. Other r. f. indicators such as neon tubes held in the field of the tank coil will indicate neutralization at minimum glow.

Under these circumstances, C_N and the tube capacitance are such that potential variations coupled through them from the grid circuit into the plate tank circuit are equal and opposite. Then with the d. c. plate voltage applied to the amplifier, feedback from the plate circuit into the grid circuit through the tube capacitance is exactly counterbalanced by that through C_N; and the amplifier acts in a simple nonoscillatory manner, reproducing in its output circuit only those effects impressed on its input circuit from the oscillator stage ahead.

c. Cross neutralization of a push-pull amplifier is accomplished by joining the plate of the number 1 tube with the grid of the number 2 tube through a neutralizing capacitor, and the plate of the number 2 tube with the grid of the number 1 tube through another neutralizing capacitor (see fig. 88①). The r. f. voltage

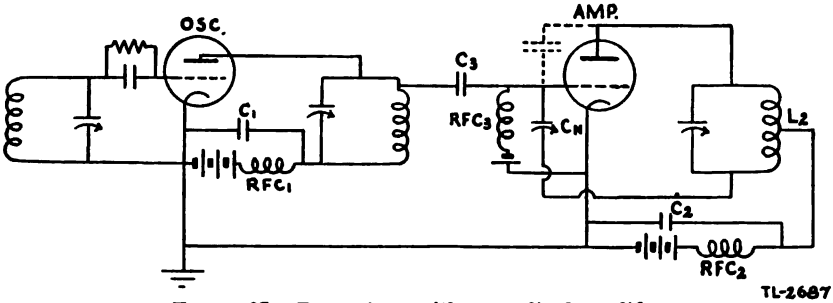
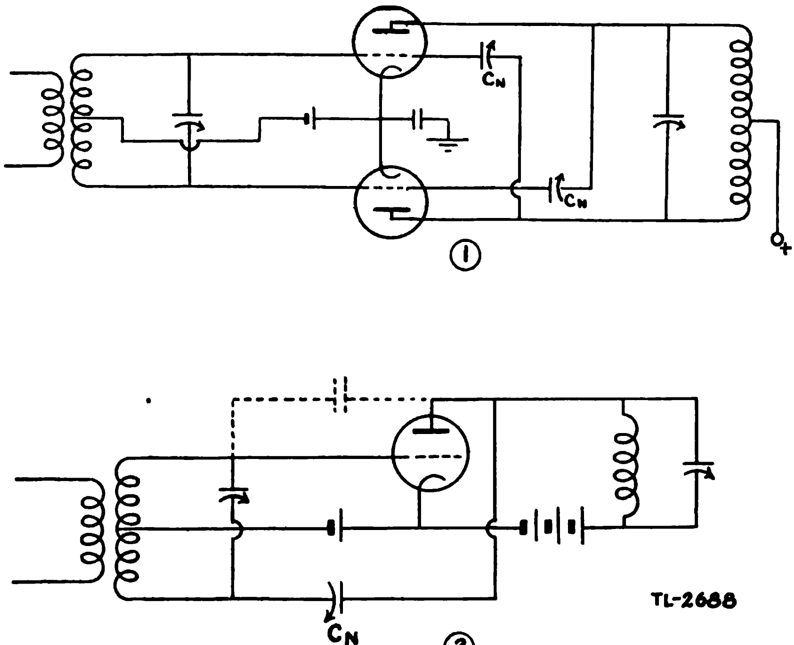


FIGURE 87.—Transmitter with neutralized amplifier.

across each neutralizing capacitor counteracts the r. f. voltage across the interelectrode capacitance of the tube to whose grid it is connected. Another method of amplifier neutralization known as the Rice system is shown in figure 88②. This arrangement is similar to that of figure 87 except that the Rice system utilizes a split input circuit in place of a split output circuit.

d. Tetrodes and pentodes eliminate the problem of neutralization of the interelectrode capacitance of the tube. However, other considerations frequently preclude their use as power amplifiers in transmitters. They are more expensive than triodes, and they require additional screen power to operate. The higher power sensitivity of tetrodes and pentodes means that less driving power is required, but at the same time increased difficulties are encountered with these tubes due to stray coupling effects between output and input circuits. These undesired input effects increase in importance as the normal input signal magnitudes are decreased.

51. Parasitic oscillations.—Circuit conditions in an oscillator or amplifier may be such that secondary oscillations occur at frequencies other than that desired. Such oscillations are appropriately termed parasitic oscillations. The energy required to maintain parasitic oscillations is wasted so far as useful output is concerned. A circuit afflicted with parasitics has low efficiency and frequently operates erratically. Figure 89 shows some of the incidental circuits which may give rise to parasitics in the transmitter of figure 87. The dotted

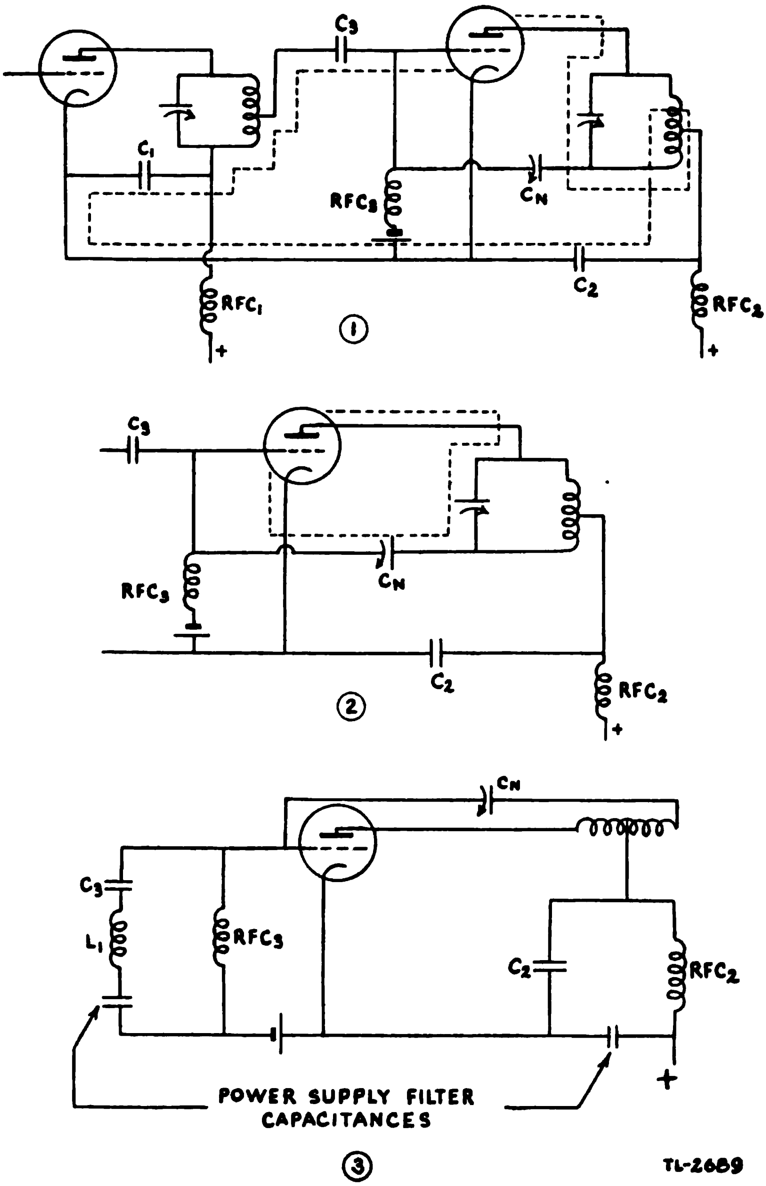


① Push-pull stage neutralization.
② Rice system of neutralization.

FIGURE 88.—Neutralization circuits.

lines of figure 89① outline a high frequency circuit, and those of ② outline an ultrahigh frequency circuit. That part of the transmitter which constitutes a possible low frequency parasitic circuit is sketched in ③. Parasitic oscillations may be suppressed by placing resistors or r. f. chokes at appropriate positions in the circuits, or by slightly modifying the existing values of circuit elements; and by using care in the physical arrangement and wiring of parts.

52. Keying systems.—*a.* A good keying system should prevent completely the radiation of energy from the antenna when the key is

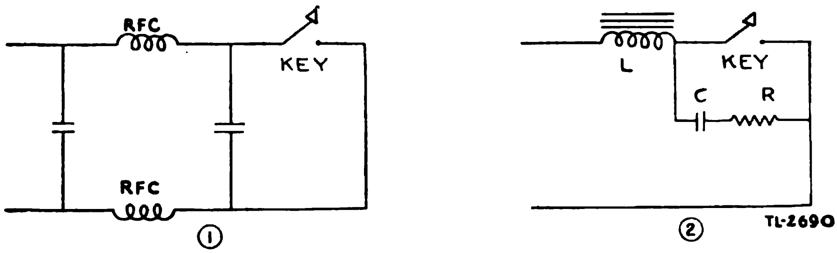


① High frequency.
② Ultrahigh frequency.
③ Low frequency.

FIGURE 89.—Parasitic oscillatory circuits in transmitter of figure 87.

open, and it should cause full power output when the key is closed. It should perform these operations without causing keying transients, or clicks, which cause interference with other stations.

b. For various reasons some energy may get through to the antenna during keying spaces. The effect is then as though the dots and dashes were simply louder portions of a continuous carrier. The backwave, or signal heard during the keying spaces, may appear almost as loud as the keyed signal; under these conditions the keying is hard to read. A pronounced backwave often results when the amplifier stage feeding the antenna is keyed. It may be present because of incomplete neutralization of the final stage, allowing some energy to get to the antenna through the grid-to-plate capacitance of the tube, or because of magnetic pickup between the antenna coupling coils and one of the low power stages. Such a condition can often



① R. f. filter to absorb transients.
② Lag circuit to prevent transients.

FIGURE 90.—Key filters.

be remedied by proper neutralization, or by rearranging the tank circuits to eliminate unwanted coupling, or by shielding.

c. When a transmitter is keyed in such a manner that the power is applied and removed suddenly, an abnormally high current surges back and forth momentarily at the time of opening and closing the key. During these brief periods the transmitter is shock excited. A mechanical example of shock excitation is the tapping of a bell with a hammer to produce vibrations in the bell. Shock excited oscillations, either mechanical or electrical, are usually highly damped and of a broad band of frequencies. The radiation accompanying shock excited oscillations in a transmitter can be detected in receivers tuned to frequencies which are widely different from that on which the main transmitting is being performed. Since duration of the shock excited oscillation is short, the result is a click in the affected receiver at the beginning and ending of each code character. A key filter such as shown in figure 90① may be employed to absorb

these transient oscillations, or the transients may be prevented by using a lag circuit as in figure 90②. The inductor or "choke" L in the lag circuit delays the rise of keying current and so prevents transients at the start of each character, while the capacitor C absorbs the current which would flow with the collapse of the magnetic field of the choke on the opening of the key. The resistor R is necessary only if the key opens and closes high potentials. Under these circumstances and with no resistor, the capacitor would attain a charge during open key periods, and a spark would occur at the key causing the contacts to stick due to development of heat. With the resistor in the circuit the energy of the charged capacitor is dissipated in it rather than across the key contacts. Also, the resistor serves to reduce the rate of change of current in charging and discharging the capacitor, which in turn reduces the shock effect on the transmitter circuit.

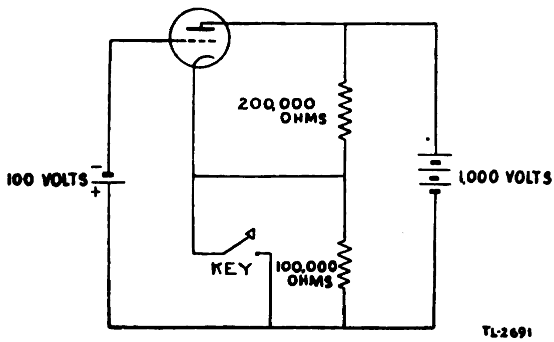


FIGURE 91.—Blocked-grid keying of amplifier.

d. The grid circuit of an amplifier is generally chosen for keying because of the relatively small currents therein. Figure 91 illustrates blocked-grid keying. With the key up, two-thirds of 1,000 volts, or 667 volts, is across the 200,000 ohm resistor; that is, 667 volts is applied to the plate; and one-third of 1,000 volts, or 333 volts, is across the 100,000 ohm resistor, so that $333+100=433$ volts negative bias is applied to the grid. No plate current can flow under these conditions. With the key down and short-circuiting the 100,000-ohm resistor, the full 1,000-volt plate supply potential appears across plate to cathode, while the grid bias is reduced to 100 volts, under which conditions the amplifier operates normally.

53. Frequency doublers.—Self-excited oscillators for transmitters offer the advantage of flexibility of adjustment to various frequencies. Crystal controlled transmitters, on the other hand, operate only on fixed frequencies as determined by the crystals available.

Crystal controlled transmitters are widely used, however, because of their excellent stability. Oscillating crystals designed for very high frequencies are quite thin and fragile, and low radio-frequency crystals are generally employed in conjunction with frequency doublers. A frequency doubler is an amplifier which is so constructed and operated as to yield an output current which is of twice the frequency of the input voltage. An ordinary distorting amplifier with its plate circuit tuned to the second harmonic of the input frequency is often employed as a doubler. More efficient doubling, without employing tube distortion characteristics, is obtained from a double ended push-push amplifier. The two tubes in a push-push amplifier have their grids connected in push-pull and their plates connected in parallel as in figure 92.

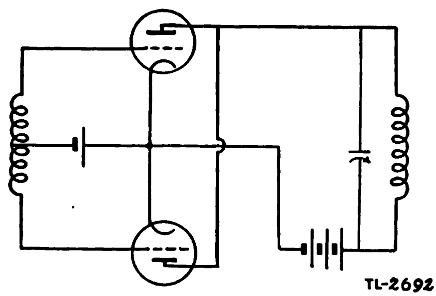
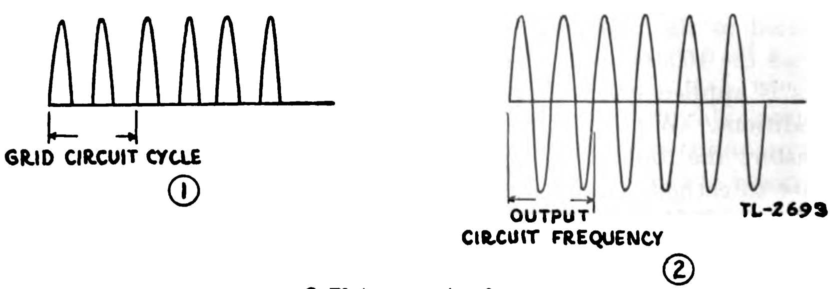


FIGURE 92.—Push-push amplifier.

Thus the tubes work alternately, and the output circuit receives two impulses in the same direction for each r. f. cycle at the grid circuit, giving all second harmonic or double frequency output in the plate circuit. Figure 93① shows plate current pulses of a push-push amplifier with tubes operated class C. The missing half cycles are supplied by the tank circuit to produce a continuous second harmonic output as in figure 93②.



① Plate current pulses.
② Output current for push-push amplifier with tubes operated class C.

FIGURE 93.

Section VIII

MODULATED TRANSMITTERS

54. Amplitude modulation.—Modulation is the variation of a radio wave at audio frequencies. Frequency modulation, variation of the frequency of the radiated wave, is discussed in section XII. Amplitude modulation, variation of the amplitude of the radiated signal, is accomplished by introducing both an audio frequency signal, say of 500 cycles, and a radio frequency signal, say of 1,000,000 cycles, into a nonlinear amplifier. The resultant sum and difference fre-

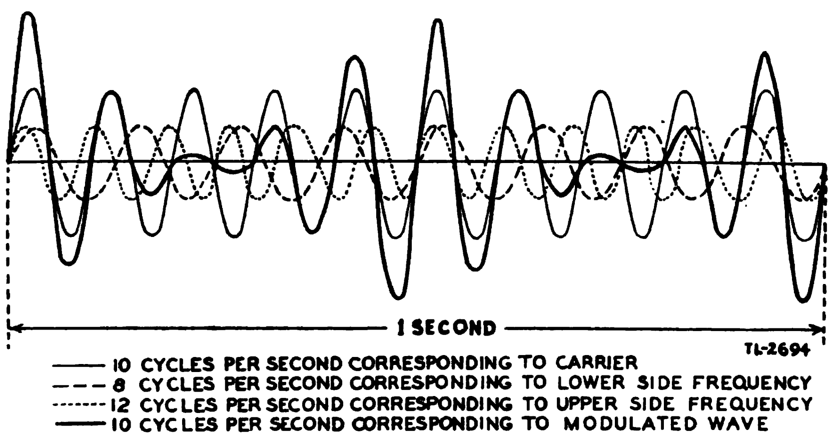


FIGURE 94.—Modulated wave showing "carrier" and "side bands."

quencies, 1,000,500 and 999,500, which convey the intelligence, are known as the side bands. The 1,000,000 cycle component is known as the carrier. Figure 94 illustrates a modulated wave as a sum of carrier and two side band frequencies. For simplicity of illustration the frequencies chosen in the figure are very low; however, the effects are similar to those in a modulated radio wave. An actual telephone transmitter side band consists of not one single frequency but contains as many frequencies as are present in the modulating signal, so that for reasonably good quality voice operation, side bands

occupy at least 3,000 cycles of the frequency spectrum either side of the carrier. Broadcast stations require side bands up to 10,000 cycles wide to convey musical programs properly. Those tuned circuits, both in transmitters and receivers, which accommodate modulated r. f. currents must be sufficiently broad to give good response to all the side band components.

55. Degree of modulation.—The degree of modulation is expressed by the percentage of the maximum amplitude deviation from the normal value of the r. f. carrier. If the positive peak r. f. current reaches twice the normal value carrier current, the negative peaks being zero, the wave is said to be modulated 100 percent (fig. 95). The effect of a modulated wave as measured by receiver response is proportional to the degree of modulation. A 10-watt carrier modulated 100 percent is about as effective as a 40-watt carrier modulated 50 percent.

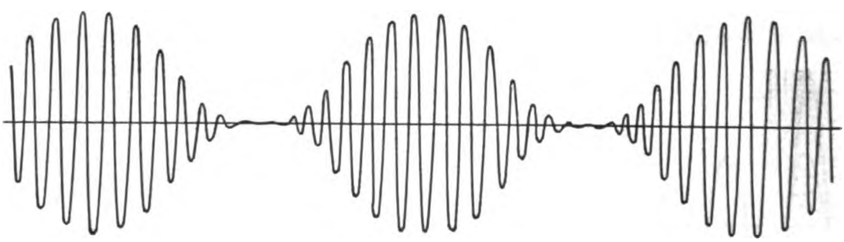

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FIGURE 95.—100 percent modulation.

56. Power relations in modulated transmitter.—The amount of power required to modulate a transmitter depends on the percentage and type of modulation. To modulate a carrier 100 percent with a single sine wave of audio frequency requires an audio power equal to one-half of the r. f. carrier power. This is because with 100 percent modulation the amplitude of each side band is one-half the amplitude of the carrier. Power is proportional to current squared; thus each side band carrying one-half the current of the carrier requires one-fourth the power. However, the power required under modulation is one and one-half times the normal unmodulated power. With voice modulation the greater portion of the audio frequency components will not modulate the carrier 100 percent, so that the power increase for voice modulation is considerably less than for single tone modulation. Since the power is increased during modulation, the reading of an antenna ammeter rises when the transmitter is modulated. One of the operating tests of a modulated transmitter is to whistle into the microphone and watch for an increase in the

antenna current. For 100 percent modulation with a single sine wave the antenna current increases approximately 22 percent.

57. Modulation methods.—Various methods of modulating a transmitter are in use. The audio frequency modulating voltage can be applied to the plate of one of the transmitter amplifiers to cause the output to vary in accordance with the audio frequency. This is known as plate modulation. Application of the audio frequency voltage to the control grid is referred to as grid, or as grid bias, modulation. A pentode power amplifier can be modulated by applying the audio frequency to the suppressor grid. This is known as suppressor modulation. The screen grid can also be modulated in

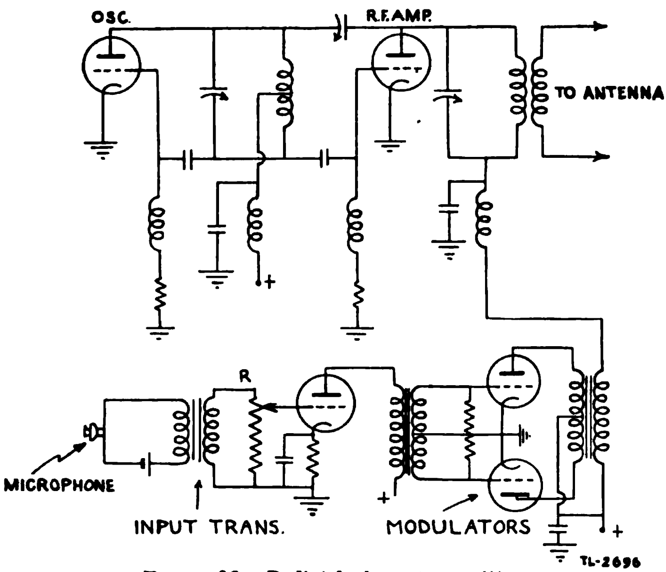


FIGURE 96.—Radiotelephone transmitter.

a tetrode. Cathode modulation, in which the audio voltage is applied in the cathode circuit, is a combination of plate and grid modulation.

58. Radiotelephone transmitter.—Figure 96 shows the basic circuits of a complete radiotelephone transmitter. Sound waves impinging on the diaphragm of the microphone alternately compress and release the carbon granules of the microphone button, thereby varying the resistance of the microphone circuit and giving rise to a voice frequency pulsating current in the input transformer primary. The potentiometer *R* across the secondary of this transformer is a volume control to regulate the amplitude of the modulating signal. The grid-to-cathode resistance of the modulator tubes

varies with the intensity of the signal, and resistors are connected across the inputs of these tubes to keep the net load impedance on the first speech amplifier tube nearly constant. These shunting resistors are much lower than the grid-to-cathode resistances, so that changes in the grid-to-cathode resistances have only a slight over-all effect on the load to the preceding circuit. The modulator output varies the plate voltage applied to the amplifier stage of the transmitter to produce corresponding variations in the radiated energy (fig. 97). The input speech amplifier stage can be converted into an audio frequency oscillator by providing a switch which, when closed, will

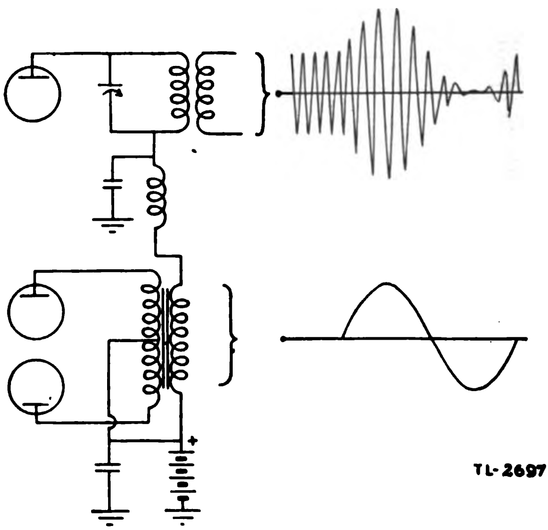


FIGURE 97.—Production of a modulated wave.

couple enough of the plate circuit energy through a capacitor back to the grid circuit to cause sustained oscillations to take place. In this way a combination continuous wave, tone, and voice transmitter results.

59. High and low level modulation.—When the final r. f. stage of a transmitter is modulated, the modulation is described as high level, since the modulation takes place at the highest power level in the system. If the modulation takes place in an intermediate stage with a higher power amplifier or several such stages following, it is called low level. In low level modulation, amplifiers which are used to increase the power output from the modulated stage are operated as linear amplifiers, that is, in such a manner that their a. c. output potentials faithfully reproduce the applied grid potentials. These

amplifiers are operated class B, and include r. f. load resistors similar to those across the inputs of the modulators of figure 96 to prevent such distortion as might otherwise accompany the change of load impedance to the preceding stage with changes in the amplitude of the modulated signal.

60. Reduction of normal carrier power for phone operation.—A modulated amplifier must handle peak currents which are twice the normal unmodulated magnitude. This means that during modulation an amplifier must be capable of handling up to four times the power it dissipates under steady intervals of unmodulated carrier output. For this reason in a transmitter which is designed for both continuous wave and phone service, the modulated amplifier stages are always reduced in carrier power output for phone operation.

Section IX

VACUUM TUBE DETECTORS

61. Detection.—The conversion of r. f. energy in a receiver into audible sound frequencies to convey intelligence is accomplished by a process called detection or demodulation.

62. C. w. detection.—For the reception of continuous wave (c. w.) signals, the output of a local oscillator, say 1,001,000 cycles, is combined with the incoming signal, say 1,000,000 cycles, and applied to a class B amplifier. The local oscillator is usually the amplifier itself, in which case the amplifier is called a heterodyne detector (fig. 98). The output of the detector contains current of the sum frequency, 2,001,000 cycles, and of the difference frequency, 1,000 cycles. The former, the r. f. component, serves no useful purpose and is bypassed to ground. The latter, the a. f. component, actuates the earphones or loudspeaker, usually through an audio amplifier.

63. Phone detection.—For phone or tone reception a separate oscillator is not necessary, since the side bands differ from the carrier by the wanted voice frequencies. Here a simple diode rectifier, as in figure 99①, is adequate. An analysis of the equivalent circuit of figure 99② shows that the load resistance should be large (in comparison with the plate-to-cathode resistance) in order to develop a large a. f. output voltage across it. In practice the load resistance is

generally made from 20 to 100 times the internal resistance of the tube. Diode rectifier action is shown in figure 46.

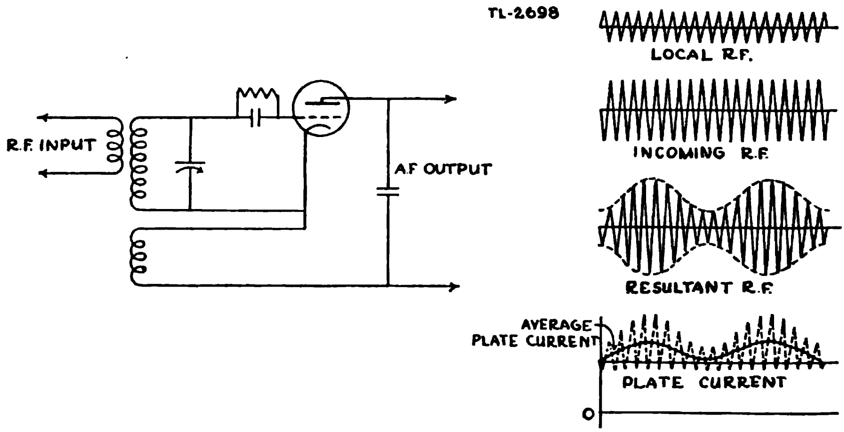
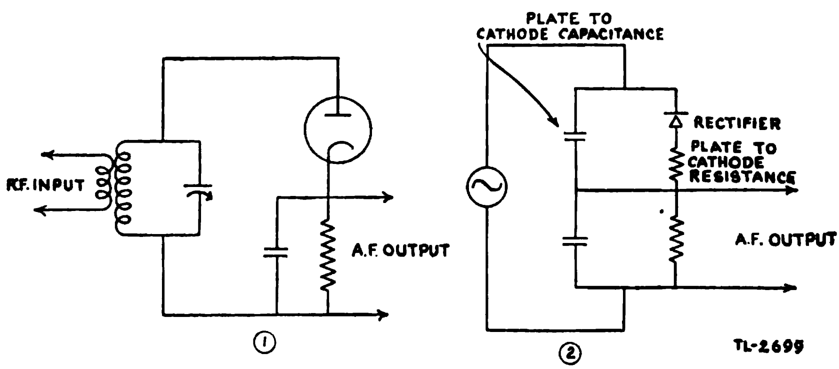


FIGURE 98.—Basic heterodyne detector circuit, and (right) how the local and incoming r. f. signals combine. The local, incoming, and resultant r. f. currents are actually alternating in nature, but the plate current of the detector tube remains direct current which is changed at the average rate, as the lowermost curve shows, to produce an audio frequency signal. For this reason, the "average plate current" curve is shown above the plate current zero line.

64. Plate and grid detection.—A single tube combining both amplification and detection is sometimes employed to obtain increased output at the sacrifice of quality. In the circuit of figure 100 ① the

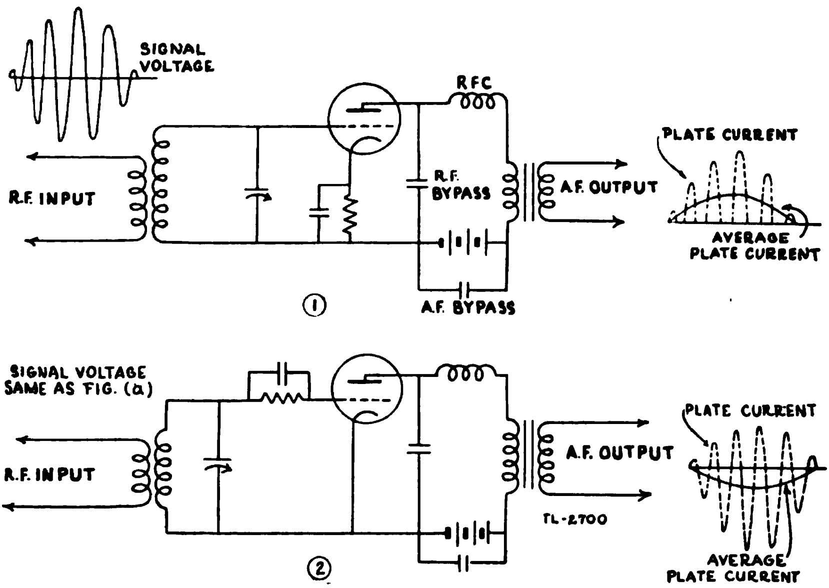


① Diode detector. ② Equivalent circuit.

FIGURE 99.

tube operates at the heel of the i_p-e_p characteristic, as determined by the grid bias and by the plate potential, and amplification occurs before demodulation. The process is referred to as plate detection. In

the circuit of figure 100② the tube operates at the heel of the i_g–e_g characteristic, as determined by the grid leak bias and by the plate potential, and demodulation occurs principally first (in the grid circuit) with amplification following. This process is called grid leak, or simply grid detection.



① Plate detector.
② Grid detector.

FIGURE 100.

65. Comparison of detection methods.—Both diode and grid leak detectors draw current from the tuned circuit, thereby lowering both the selectivity and the gain of the tuned circuit. A properly designed diode detector gives less distortion than either of the other types; and usually the plate detector gives less distortion than the grid leak type. Grid leak detection was formerly used extensively for the detection of weak signals, but the development of improved radio frequency amplifiers has made the grid leak detector almost obsolete. The d. c. component produced in the diode detector is frequently used for effecting automatic volume control.

Section X

RECEIVERS

66. Tuned r. f. receiver.—*a.* Figure 101 shows the schematic circuit of a tuned radio frequency (t. r. f.) receiver. This receiver has one stage of tuned radio frequency amplification, a plate detector, and one stage of audio frequency amplification. The two resonant circuits are tuned by a ganged variable capacitor which has all rotor

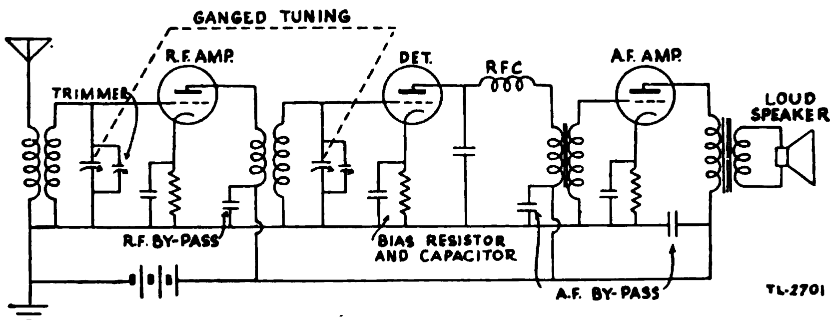


Figure 101.—Tuned r. f. receiver.

plates connected to the same shaft so that both circuits can be adjusted with a single dial. Small trimmer capacitors connected in parallel with the main capacitors compensate for inequalities in circuit constants. These trimmers are usually screw driver or socket wrench controlled from the rear or bottom of the receiver chassis.

b. The trimmer adjustment should be made at the high frequency end of the band, that is, with the main capacitor plates out of mesh. If this adjustment were attempted at the low frequency end of the band with the capacitor plates in mesh, it would take a large change in the trimmer capacitance to cause any noticeable change in the total capacitance. On the other hand, with the tuning capacitors out of mesh and presenting only a small capacitance, a minute change in the trimmer capacitance represents an appreciable change in the total capacitance, and it is possible in this way to get a critical adjustment.

c. To compensate for slight inequalities of the two tuning capacitor sections, the end plates are sometimes slit in such a way that just a portion of these plates can be bent slightly. This provides a means of alining the two circuits at various settings of the tuning capacitors so that the circuits track over the entire band.

67. Volume control.—*a.* Volume controls can be inserted in almost any circuit. Some receivers employ volume controls in more than one circuit. A popular method of volume control is the use of a variable resistor in a cathode return circuit to regulate the bias on a variable μ tube. Automatic volume control, abbreviated a. v. c., may be had by taking the bias for one or more r. f. variable μ tubes partly from the rectified input signal. In this way the amplification given to a particular tube can be decreased in accordance with the strength of the signal to provide a fairly uniform response at the expense of a certain amount of sensitivity. Automatic volume con-

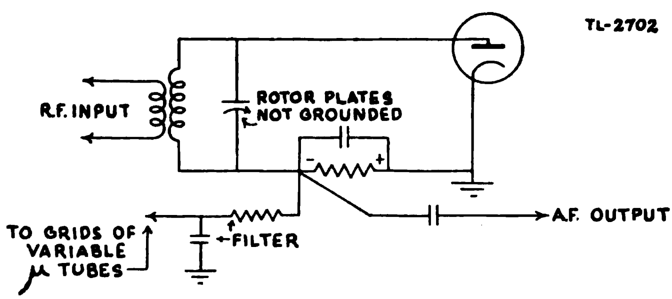


FIGURE 102.—Automatic volume control circuit.

trol is particularly desirable for receivers in mobile craft wherein the signal strength changes as the vehicle is maneuvered. Figure 102 shows a detector diode with an a. v. c. circuit.

b. The variable μ tube is designed to operate with a minimum bias of about 3 volts. This minimum bias is usually provided by a cathode resistor, and the a. v. c. bias is in series with it. A disadvantage of ordinary a. v. c. is that with it even the weakest signal reduces the amplification slightly. An adaptation which avoids this is shown in figure 103 and is referred to as delayed automatic volume control (d. a. v. c.). In this particular circuit the a. v. c. diode is separate from the detector diode, and both are housed in the same vacuum tube along with a pentode amplifier. The tube is called a duplex-diode pentode. Part of the energy which is fed to the plate of the detector diode is coupled to the a. v. c. diode section by the small capacitor *C*. By means of a cathode biasing resistor *R* the plate of the a. v. c. diode is maintained at a negative voltage which keeps it from rectifying and

producing the a. v. c. voltage until the peak voltage coupled to it through C counterbalances this diode's negative voltage. For very weak signals, which do not produce enough voltage on the plate of the

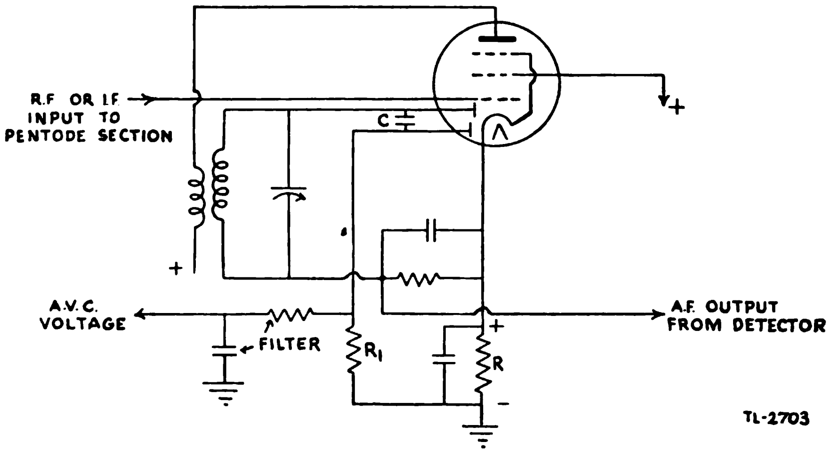


FIGURE 103.—Delayed automatic volume control.

a. v. c. diode to overcome the existing negative potential, no a. v. c. voltage is developed, and thus the sensitivity of the receiver remains the same as if a. v. c. were not being used. On the other hand, when normal strength signals are being received, which do not need the set's

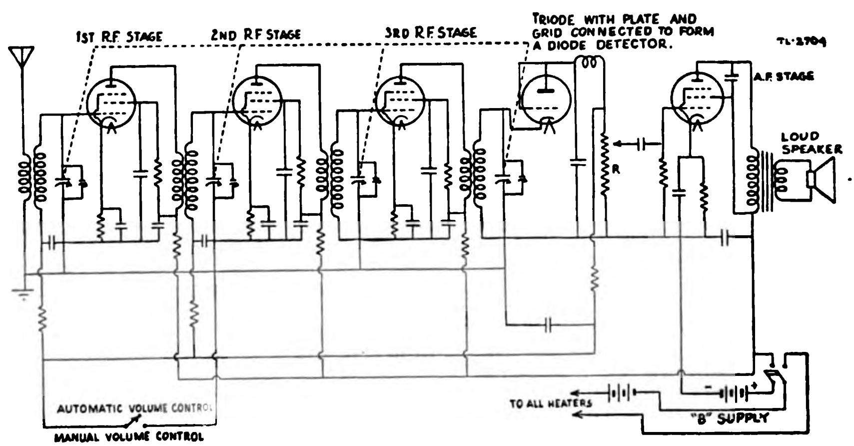


FIGURE 104.—T. r. f. receiver with automatic volume control.

maximum sensitivity, enough voltage will be coupled to the a. v. c. diode to overcome the small negative plate potential and produce an a. v. c. voltage drop across resistor R_1. This voltage has the a. f. and r. f.

components filtered from it and is applied to the grids of the variable μ tubes just as in the case of the ordinary a. v. c.

68. Circuit of tuned r. f. receiver.—Figure 104 shows the complete circuit of a tuned radio frequency (t. r. f.) receiver employing

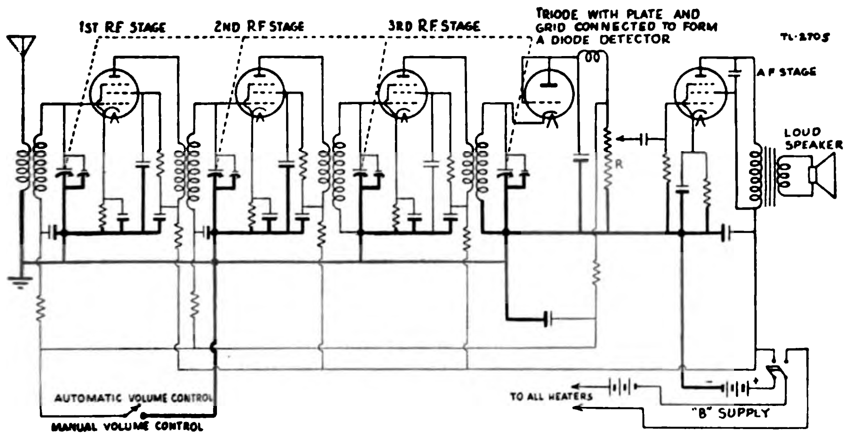


FIGURE 105.—T. r. f. receiver. Ground potential elements denoted by heavy lines.

three r. f. pentode stages with automatic volume control on the first two stages only. A switch is provided for short-circuiting the a. v. c. when it is desired to use the manual control (detector output po-

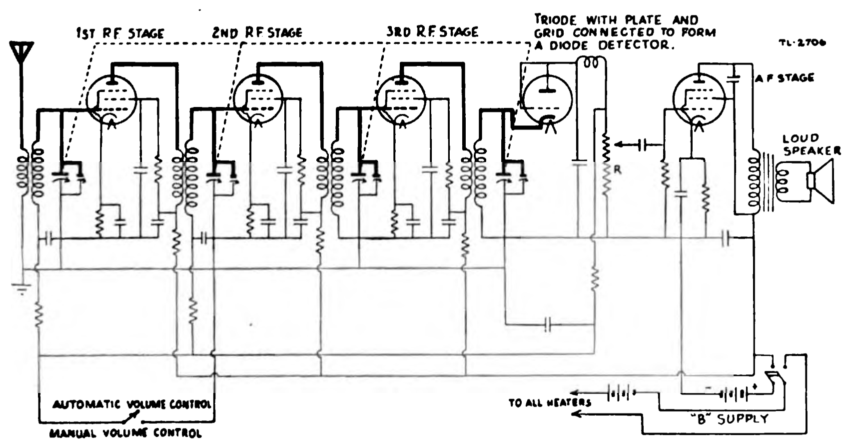


FIGURE 106.—T. r. f. receiver. Elements at high r. f. potential denoted by heavy lines.

tentiometer *R*) exclusively. Figures 105 through 109 reproduce the same receiver wiring diagram with various circuits emphasized to facilitate study.

69. Superheterodyne receiver.—*a.* The superheterodyne has replaced almost all other types of general purpose receivers at the present time. Figure 110 shows the scheme of a superheterodyne receiver

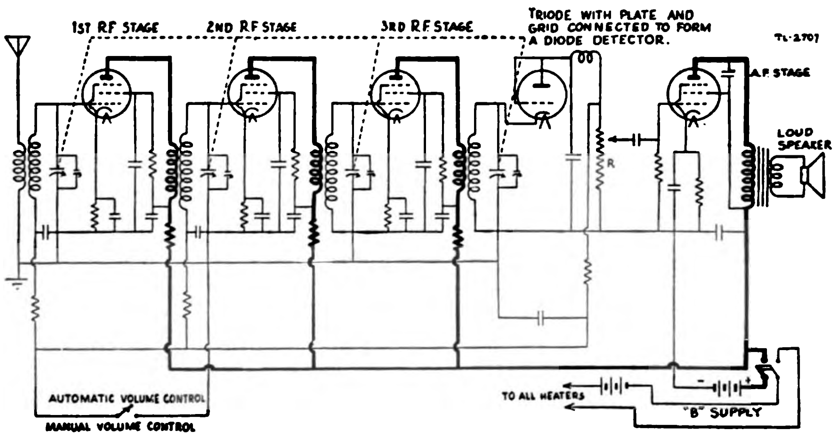


FIGURE 107.—T. r. f. receiver. D. c. plate supply shown by heavy lines.

by means of a block diagram. The two novel features of a superheterodyne receiver are the mixer stage and the intermediate frequency (i. f.) amplifiers. The mixer stage is often referred to as the first detector. In reality it is a heterodyne detector which, in

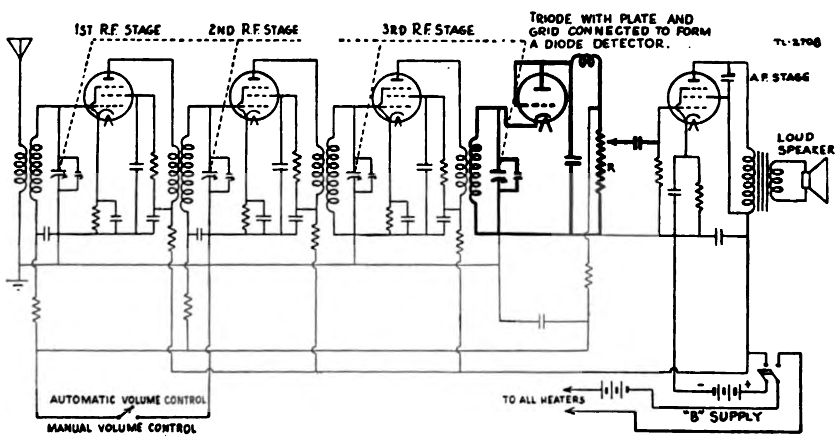


FIGURE 108.—T. r. f. receiver. Detector circuit shown in heavy lines.

conjunction with an appropriately tuned local oscillator, converts the r. f. input signal to a lower frequency, still r. f., which for identification is called the intermediate frequency. The second de-

tector, or demodulator, converts this intermediate frequency energy to audio frequency.

b. The mixer may be operated as a plate detector with the exception that instead of filtering the r. f. from the output, here a band pass filter is used which eliminates all frequencies except the intermediate

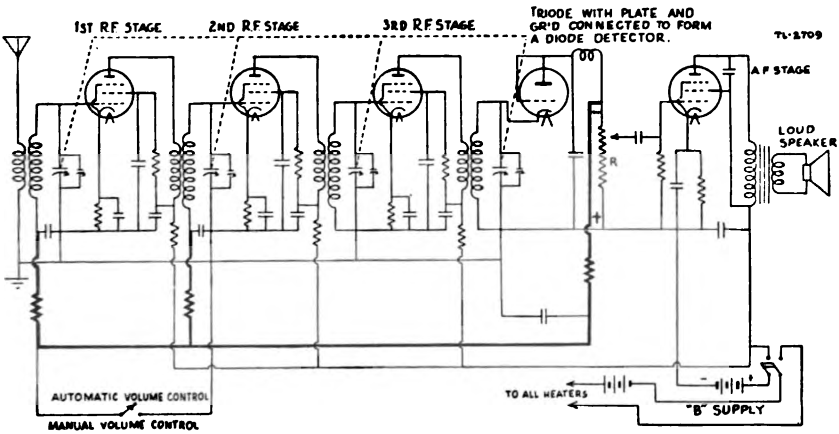


FIGURE 109.—T. r. f. receiver. A. v. c. circuit shown in heavy lines.

band which is desired. This band pass filter is actually a transformer with both primary and secondary tuned. The coupling is such as to produce a resonance curve which is flat topped to accommodate a narrow band of frequencies in the manner of the curve of figure 29②. The fixed intermediate frequency permits simplicity of

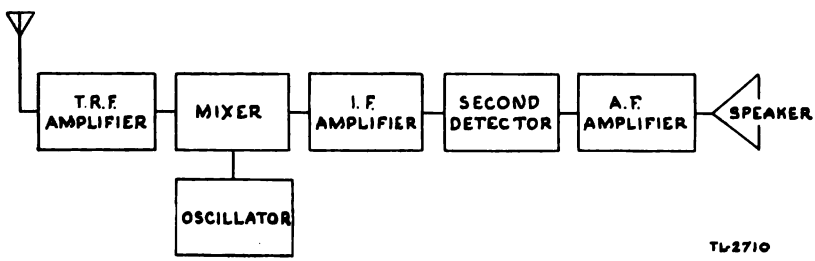


FIGURE 110.—Scheme of superheterodyne receiver.

design to concentrate on optimum selectivity and amplification at this one particular frequency. At the relatively low intermediate frequencies employed, of the order of 500 or 1,000 kilocycles (kc.), stray capacitances are not especially troublesome, and standard pentode tubes give good voltage gain. Tuning the plate circuits allows

the i. f. amplifier tubes to work into high impedance plate loads, another factor contributing to high gain.

c. The local oscillator circuit capacitor is ganged to the tuning capacitors in such a manner as to generate oscillations of a frequency which differs from the signal frequency by an amount equal to the fixed intermediate frequency. Suppose, for example, that the desired incoming signal has a frequency of 1500 kc. and that the i. f. amplifier is tuned to 465 kc. Then if the local oscillator is adjusted to 1965 kc., the mixer stage will yield (among other frequencies, which are rejected by the tuned circuits) 1965−1500=465 kc. Incidentally, a 465 kc. output of the mixer stage also results if a 2430 kc. incoming signal is present at the same time: 2430−1965=465 kc. In such a case 2430 kc. is referred to as an image frequency, since it is an image

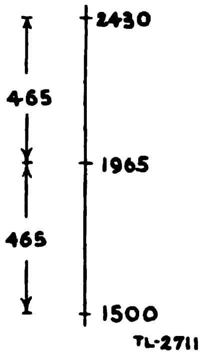


FIGURE 111.—Illustrating image frequency.

in the frequency spectrum, so to speak, of the 1500 kc. frequency about the 1965 kc. oscillator frequency (fig. 111). The tuned circuits ahead of the mixer stage are tuned to the desired frequency, 1500 in this case, so that the preselector amplifies the desired signal much more than it does the image signal. The ratio of desired signal to image signal at the mixer input is known as the image ratio and in a good superheterodyne receiver may be around 1,000.

70. Pentagrid mixer.—The plate detector mixer has the disadvantage of effectively coupling a load back through the interelectrode capacitance into the input circuit, so that tuning the input circuit affects the frequency of oscillations. A pentagrid (five-grid) mixer tube connected as in figure 112 isolates the oscillator and mixer circuits. The signal and mixer grids are screened by the two adjacent grids. The fifth grid is a suppressor.

71. Converter.—A single tube performing the functions of both oscillator and mixer is known as a converter. Figure 113 shows the connections to a pentagrid converter. The grid nearest the cathode forms the control grid, and the next grid, the plate of a triode oscillator. The first grid is called the oscillator grid and the second, the anode grid. The signal is applied to the fourth grid, the third

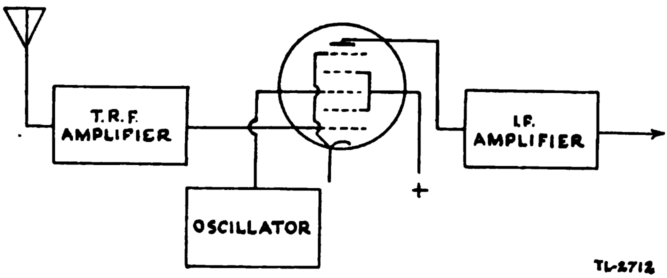


FIGURE 112.—Pentagrid mixer.

and fifth grids forming electrostatic screens. The oscillator "plate" current, which is flowing in pulses, causes electrons to shoot through the openings in the anode grid in spurts at the oscillator frequency. The effective plate current is similar to that for the pentagrid mixer, in which two grids modulate a continuously emitted space charge. Pentagrid converters offer the advantage of simplicity of tubes and of wiring. However, at higher than broadcast frequencies, that is, for

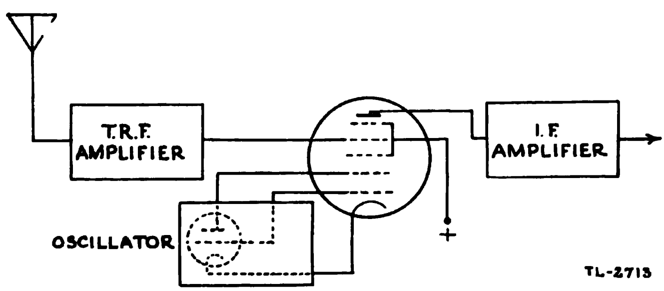


FIGURE 113.—Pentagrid converter.

most communication frequencies, their usefulness is limited by interaction which occurs between the oscillator and signal sections. A detailed circuit of the pentagrid converter is shown in figure 114.

72. Circuit of superheterodyne receiver.—Figure 115 shows the circuit of a six-tube superheterodyne receiver. This receiver has one stage of t. r. f. preselection, a local triode oscillator, a mixer, two stages of i. f. amplification, a diode detector with delayed a. v. c.,

and a power pentode output stage. A beat frequency oscillator is included for c. w. reception. Particular individual circuits of the receiver are emphasized in figures 116 to 119.

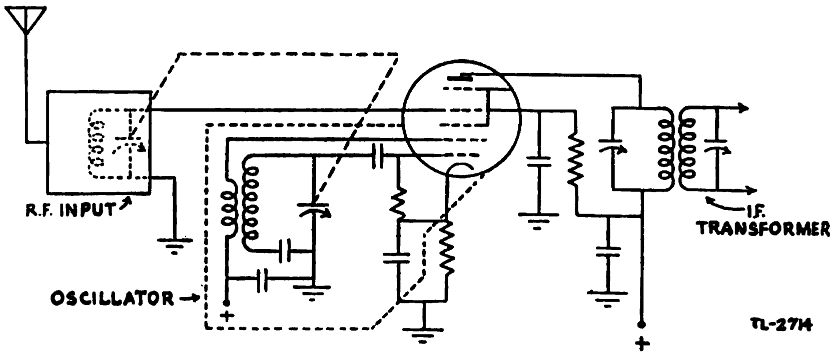


FIGURE 114.—Pentagrid converter circuit.

73. Crystal filter.—*a.* The characteristics of the quartz crystal make it particularly suitable for use in an i. f. stage of a superheterodyne receiver. The crystal serves two functions, namely, to increase the over-all selectivity of the i. f. amplifier and to permit the

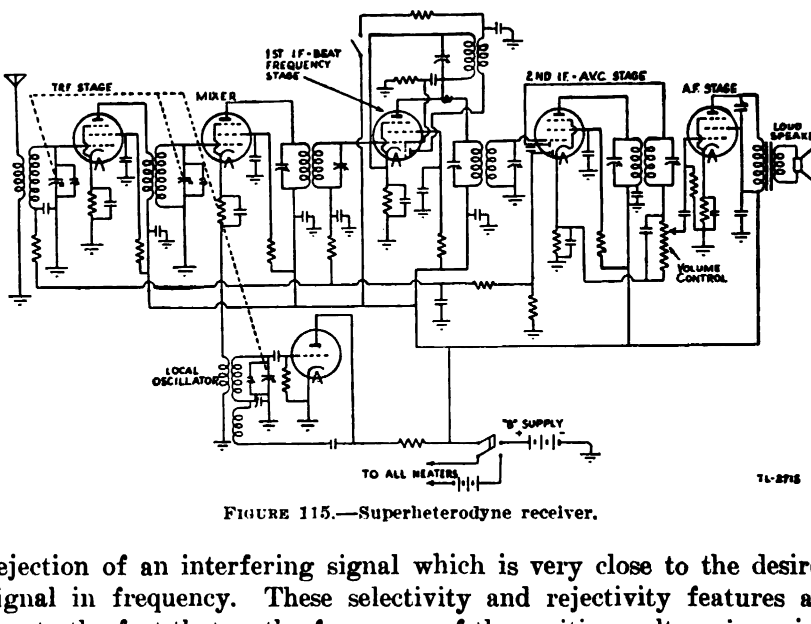


FIGURE 115.—Superheterodyne receiver.

rejection of an interfering signal which is very close to the desired signal in frequency. These selectivity and rejectivity features are due to the fact that as the frequency of the exciting voltage is varied, the crystal behaves as a series resonant circuit at one frequency,

f_r, and as a parallel antiresonant circuit at another frequency, f_a; f_a is very slightly (usually less than one part in a thousand) higher than f_r. A typical crystal circuit in an i. f. stage is shown in figure 120①.

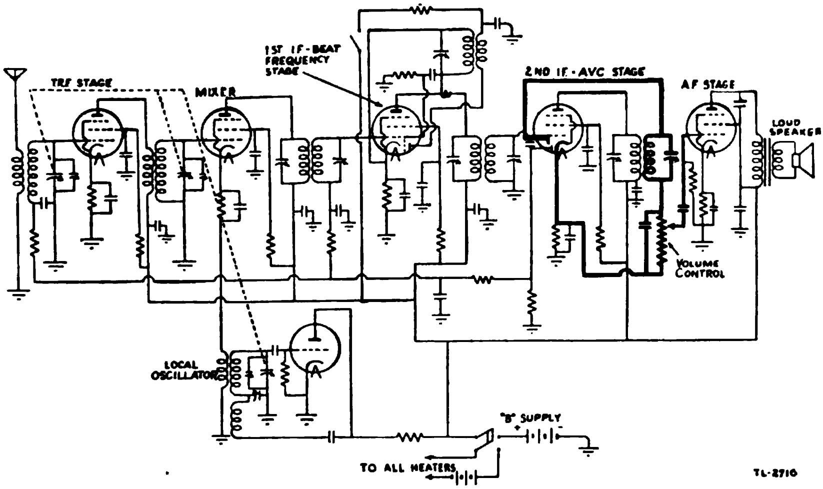


FIGURE 116.—Superheterodyne receiver. Second detector circuit shown in heavy lines.

b. At the series resonant frequency the crystal acts as a pure resistance, the magnitude of which is very small compared with the load impedance. As a consequence, at this frequency the voltage across

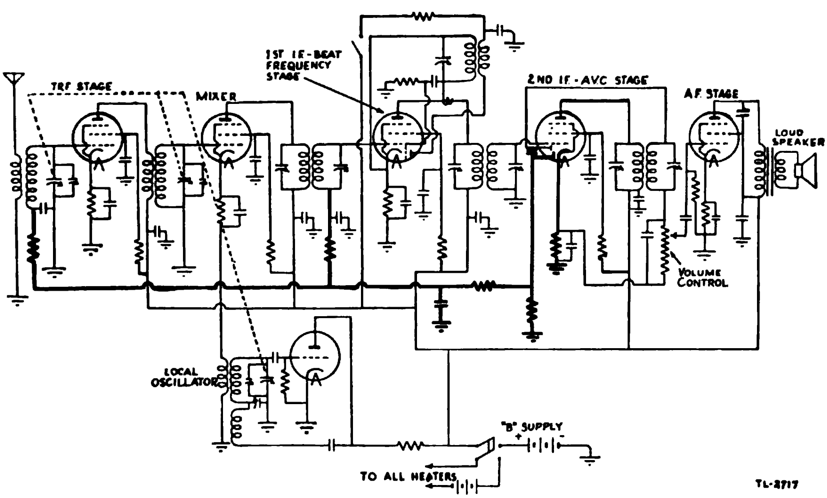


FIGURE 117.—Superheterodyne receiver. D. a. v. c. circuit shown in heavy lines.

the filter output (fig. 120②) is very nearly equal to that across L_1, that is, the output voltage is approximately one half the impressed voltage across the secondary coil L_1L_2. At all frequencies sufficiently

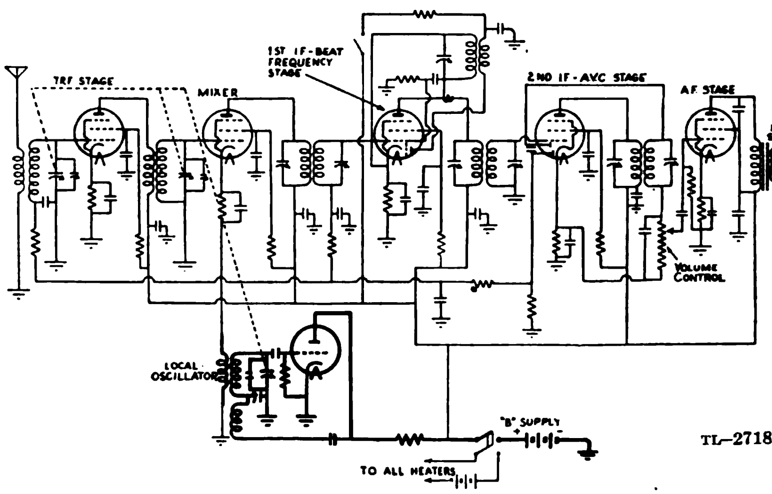


FIGURE 118.—Superheterodyne receiver. Local oscillator shown in heavy lines.

remote from the crystal's resonant frequencies, the crystal presents a capacitative reactance due to the capacitor formed by the holder plates and the quartz dielectric. This reactance is relatively high as

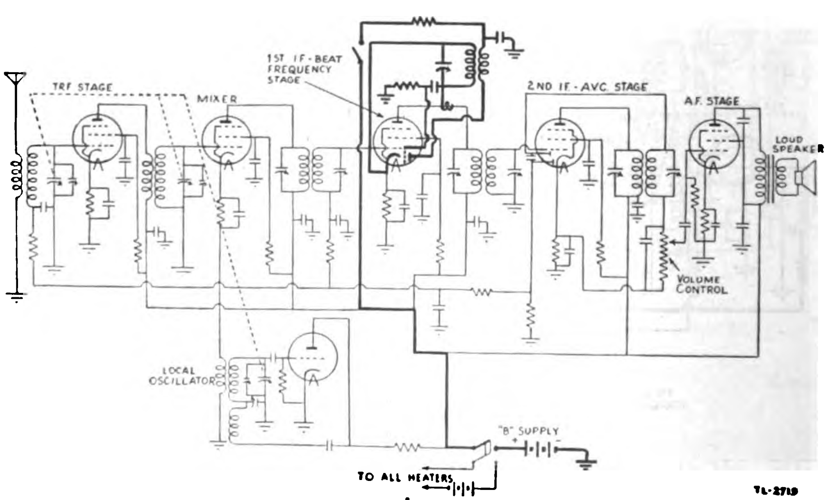
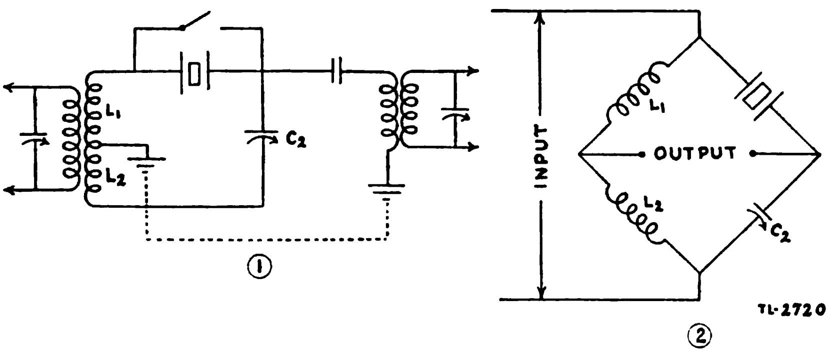


FIGURE 119.—Superheterodyne receiver. Beat frequency oscillator for c. w. reception shown in heavy lines.

compared with the load impedance, so the voltage developed across the load impedance is very small.

c. A signal which is so separated in frequency from the desired signal as to cause an audible note in the receiver can be rejected by use of the phasing capacitor C_2. To accomplish this, the local oscillator must be tuned, by adjusting the main receiver dial if necessary, so as to bring the undesired (i. f.) signal on the high frequency side of the desired (i. f.) signal. Just above f_a, the crystal, while still oscillating, presents a small net capacitive reactance. The magnitude of this reactance depends on the frequency of the exciting signal. If the capacitance of the phasing capacitor, C_2, is made equal to that of the crystal at the frequency of the interfering signal, the net output at this frequency will be negligible, since the equal capacitances together with the equal inductances, L_1 and L_2,



① In i. f. stage. ② Segregated to show bridge form.

FIGURE 120.—Crystal filter.

form a balanced bridge circuit. If desired, C_2 may be set equal to the capacitance of the crystal holder, and then rejection is effective over all frequencies for which the crystal does not oscillate.

74. Multiband receivers.—Communication receivers often use one ganged set of tuning capacitors with several sets of r. f. coils to fit the particular operating bands. Alining capacitors (trimmers) are included with each set of coils so that once they are adjusted, all the circuits will tune properly with a single dial on the front panel. Some sets use plug-in coils; others have the coils permanently incorporated in the receiver with a multicontact gang switch to connect the various coils as desired. In the multiband superheterodyne receivers the only coils which need be changed are the preselector, mixer, and oscillator coils. Sometimes, when a superheterodyne is to cover an extremely wide range of frequencies, two

sets of i. f. amplifier coils are provided corresponding to two intermediate frequencies, one for the high ranges and one for the low ranges.

Section XI

POWER SUPPLIES

75. General.—Cathode power supply is furnished by batteries or by hand driven dynamotors in portable field radio sets; semiportable and mobile sets generally use storage batteries for filament heating purposes. In permanent ground installations filaments are heated from the standard a. c. lighting circuit through a step-down transformer. Grid bias for voltage amplifiers is customarily taken from the plate supply by some means of self-bias, while for large power tubes separate rectifier-filter systems or d. c. generators are frequently employed. Plate supply in lightweight field "transceivers" is by batteries. Dynamotors driven by storage batteries or by hand are favored for plate power in portable and mobile sets, while many semiportable transmitters carry gasoline engine driven generator equipment. Permanent installations ordinarily use some sort of rectifier-filter system plate supply.

76. Vacuum tube rectifiers.—Vacuum tube rectifiers for plate supply are of two general types, high vacuum and mercury vapor. The former offers the advantage of ruggedness, the latter, high efficiency. In both types the tube contains two elements, a cathode and a plate, and both operate on the principle of current flow only during intervals of positive plate potential. In the mercury-vapor tube ionization of the mercury vapor occurs at a potential of about 15 volts. The positive mercury ions, drifting to the cathode, neutralize the negative space charge surrounding the cathode and permit electrons to proceed to the plate under conditions of very low plate-to-cathode potentials. The result is that the tube carries large current with about only a 15-volt drop in potential necessary for ionization occurring across the tube itself. However, this type of rectifier is critical of operation. Positive ions fall into the cathode at a damaging rate if the voltage across the tube becomes excessive for even short intervals. For this reason the cathode must be brought to full operating temperature before the anode voltage is applied, and temporary overloads must be carefully avoided.

77. Rectifier-filter system.—A typical full wave rectifier with filter system for a receiver or small transmitter is shown in figure 121. Each plate-filament circuit of the tube acts as a half wave rectifier delivering current during alternate half cycles when its plate is positive. The filter input voltage has a wave shape as shown in figure 37. The filter of figure 121 is known as a capacitor input filter. The input capacitance is somewhat dangerous in that it causes high charging current surges when the power is applied. On the other hand, a small input capacitance reduces the effectiveness of the filter action. A choke input filter, as in figure 36, gives a lower output voltage, but it limits possible current surges and it provides good regulation; that is, it tends to maintain the output voltage constant regardless of the load current. A bleeder resistor across the filter

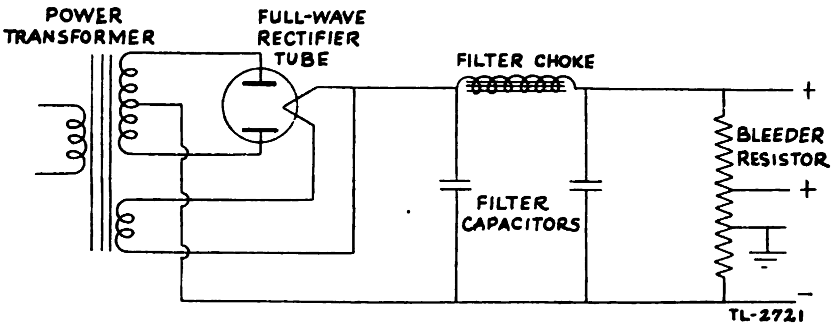


FIGURE 121.—Power supply for receiver or for small transmitter.

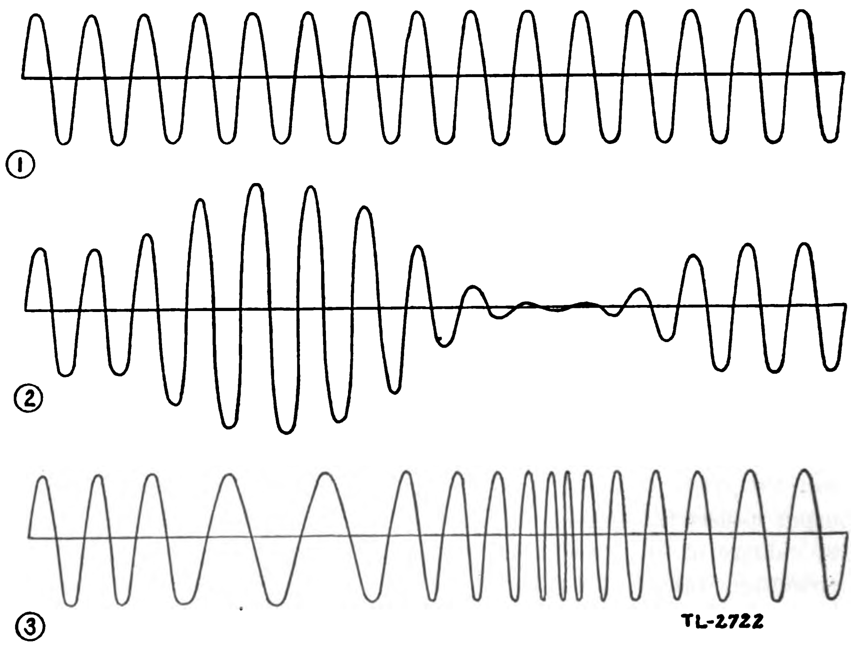
output assists the regulation in that it presents a constant load, and any change in the current drawn by the equipment causes a reduced percentage variation in the total load. A potentiometer voltage-divider and bleeder resistor may be one and the same unit.

SECTION XII

FREQUENCY MODULATION

78. General.—Frequency modulation is the process of varying the frequency of a radio frequency wave at an audio frequency rate,

without varying its amplitude. The essential difference between frequency modulation (f. m.) and amplitude modulation (a. m.) is shown in figure 122. In this figure, ① represents an unmodulated r. f. carrier; ② shows the result of amplitude modulating the carrier; and ③ shows the result of frequency modulating the carrier. In ② during the modulation period the amplitude rises and falls in accordance with an impressed audio frequency signal. In ③ during the modulation period the frequency increases and decreases in accordance with the audio signal, but the amplitude remains constant.



① Unmodulated r. f. wave.
② Amplitude modulated wave.
③ Frequency modulated wave.

FIGURE 122. Amplitude and frequency modulation.

79. Simple modulator and demodulator.—*a.* A simple form of frequency modulator is that of a condenser microphone shunting an oscillatory circuit, as in figure 123. The diaphragm in the condenser microphone (see par. 103) forms one plate of a capacitor. Sound waves striking the microphone compress and release the diaphragm to vary the capacitance at the voice frequency. Since the microphone capacitance is in parallel with the oscillatory circuit capacitance, the effect is that of changing the frequency of the r. f. oscillations at the voice frequency rate.

b. Any parallel resonant circuit, such as those in the r. f. stages of an ordinary a. m. receiver, will act as a frequency modulation detector if the operation is such that the unmodulated carrier is tuned in on one side, rather than at the center, of the response curve, as shown in figure 124. The effect of such "detuned" operation is that, as the frequency swings above and below the normal unmodulated carrier frequency, the resulting output varies in amplitude accord-

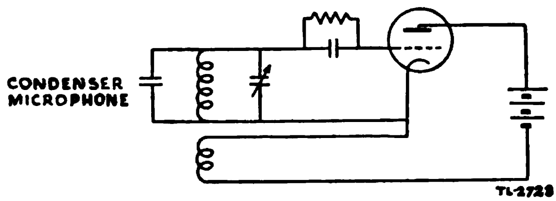


FIGURE 123.—Simple frequency modulation scheme.

ingly. This amplitude modulated signal is rectified in the ordinary manner in the detector circuit.

80. Wide swing frequency modulation.—Frequency modulation presents an appreciable signal-to-noise ratio improvement over amplitude modulation provided the frequency swing with modulation is several times as much as the highest audio frequency transmitted. A 25-kilocycle swing to each side of the unmodulated carrier fre-

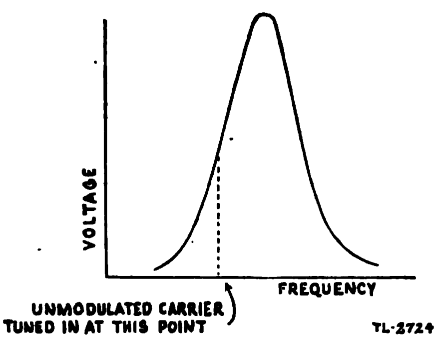


FIGURE 124.—Parallel resonant circuit as a frequency detector.

quency is common in communication work; 75-kilocycle swings are usual in broadcast service. To obtain a wide frequency swing with modulation, the oscillator frequency is usually made much lower than the desired carrier frequency, and frequency doublers are employed to multiply the original modulated frequency. If the oscillator output has a normal frequency of 10 megacycles and is modu-

lated to produce a maximum swing of 10 kilocycles, then doubling twice results in a 40-megacycle carrier with a 40-kilocycle swing.

81. Practical frequency modulator.—Both the simple modulator and the simple demodulator described in paragraph 79 are relatively inefficient. A practical frequency modulator is shown in figure 125. Modulation is accomplished by variation of the effective reactance of the oscillatory circuit at an audio frequency rate as controlled by

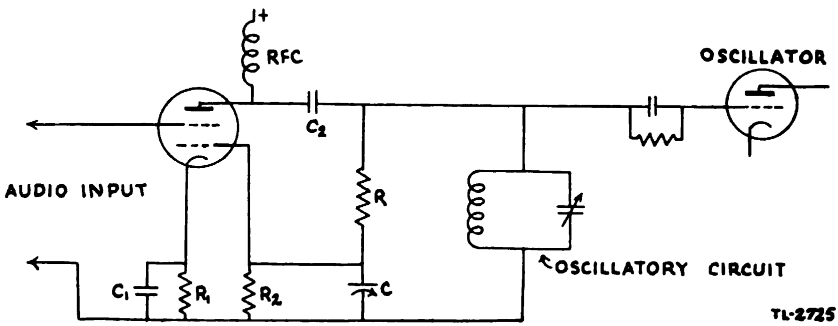


FIGURE 125.—Frequency modulator circuit.

the microphone sound impulses. C_2 is a d. c. blocking capacitor. C_1, R_1, and R_2 form a grid bias arrangement for the control grid of the modulator. R_2 is a very high resistance of the order of a megohm. The essential elements of the circuit are the small capacitance C across the modulator control grid and the high resistance R, which is in series with C across the oscillator tank circuit. The current through R–C is very nearly in phase with the voltage across R–C (fig. 126), which voltage is that across the oscillatory circuit, and the voltage

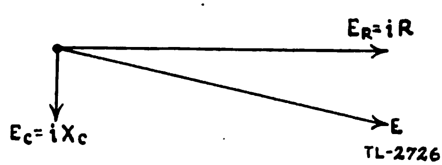


FIGURE 126.—Voltage relations in R–C circuit of figure 125 (R very much greater than X_C).

across C is practically 90° behind the voltage across the oscillatory circuit. The r. f. voltage across C (from the oscillatory circuit) is impressed on the control grid of the modulator. Audio voltages from the microphone circuit are impressed on the second grid of the modulator. The resulting audio frequency modulated r. f. plate current responses are in phase with the control grid potential, therefore 90° behind the voltage across the oscillatory circuit. The radio frequency choke in the plate circuit of the modulator offers a large re-

actance to the r. f. component of the plate current, so that this r. f. component flows through the tuned circuit of the oscillator. The total lagging current due to the voltage across the oscillatory circuit is greater than it would have been if it were not for the modulator circuit. The same effect could have been produced by connecting an inductor in parallel with the oscillatory circuit. Thus the modulator acts as an inductance. As sound waves strike the microphone, the potential of the second modulator grid is varied, and in turn, the modulator plate current. This varies the effective inductance of the oscillatory circuit, which then varies the frequency of the oscillations.

82. Frequency modulation reception.—*a.* A block diagram of a practical f. m. superheterodyne receiver is shown in figure 127. It will be seen that a receiver for f. m. differs from one for a. m. in two main aspects, the limiter and the frequency discriminator. A further essential difference is the width of the band to which the i. f. amplifier is tuned. For an a. m. receiver it is necessary only that

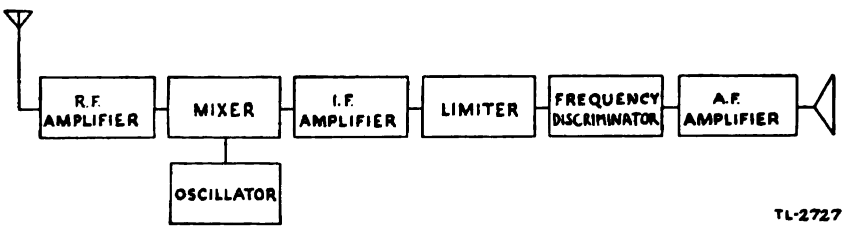


FIGURE 127.—Block diagram of f. m. receiver.

the i. f. amplifier pass a range of frequencies 30 kc. wide at the most, corresponding to the separation between the two extreme side band frequencies. In an f. m. receiver the i. f. amplifier must accept a band from 50 to 150 kc. in over-all width depending upon the maximum frequency swing employed in the transmitter. The limiter serves to remove any amplitude modulation of the signal, and the frequency discriminator extracts the audio frequency signal to feed it into an ordinary audio amplifier. The limiter stage of an f. m. receiver is shown in figure 128. The actual circuit is that of an ordinary i. f. stage, but the operating conditions are quite different. The resistor *R*1 broadens the band pass characteristics of the i. f. transformer *T*1. The d. c. voltages applied to the limiter tube are very small, about 15 volts on the plate and 10 volts on the screen. Consequently, even a rather weak signal arriving on the grid saturates the tube, and the maximum possible plate current is reached when the instantaneous voltage on the grid is considerably below the maxi-

mum value of the signal voltage. The result is that as long as the signal is above a certain minimum strength, all traces of amplitude modulation are removed by the limiter action, as shown in figures 129 and 130. Since the original transmission contained no intentional amplitude modulation, any amplitude modulation present in

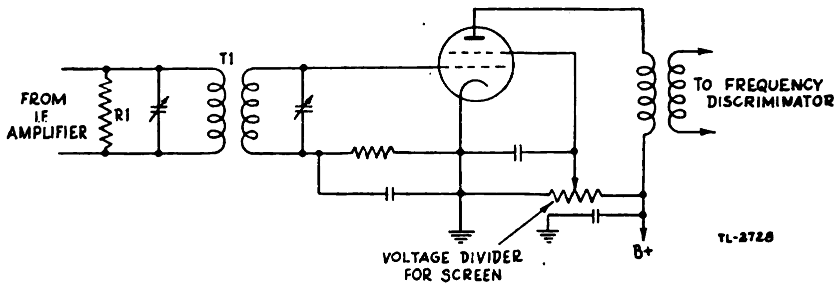


FIGURE 128.—Limiter circuit of an f. m. receiver.

the signal as received is the result of extraneous effects, including static and man-made noise; these unwanted components are removed by the limiter.

b. Figure 131 shows the actual combination of the limiter stage and the frequency discriminator stage of a typical f. m. receiver. The discriminator is the equivalent of the second detector of an ordinary

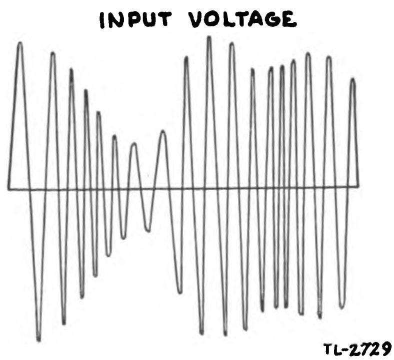


FIGURE 129.—Input signal to limiter tube, containing both a. m. noise and the desired f. m. signal.

superheterodyne, and performs the similar function of demodulating the carrier. (See sec. XI.) The i. f. transformer *T*2 has a center-tapped secondary, *S*1–*S*2, feeding the plates of a double diode rectifier. The cathodes of the latter terminate at the ends of a center-tapped resistor *R*2, one end of which is grounded. The direct current return path of the rectifier circuit, between the center tap of *S*1–*S*2 and the

center tap of $R2$, is completed through the inductor L. This coil has another function, to be explained later.

(1) The operation of the discriminator circuit in recovering the audio modulation from the f. m. signal depends on three factors. First, the center tap of $S1$–$S2$ causes a division of the signal voltage across the tuned circuit $S1$–$S2$–$C2$, this voltage being induced by the primary P in the usual electromagnetic fashion. The second factor is that the

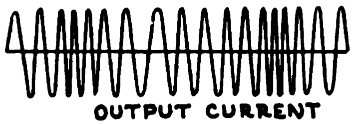


FIGURE 130.—Output of the limiter tube. The a. m. impulses have been chopped off.

signal voltage across P is also impressed across inductor L because of the direct connection afforded by the coupling capacitor $C1$. Note that the coil L is common to both halves of the secondary of $T2$ with respect to the signal voltages applied to the two sections of the double diode. This means that two voltages are impressed on each diode: the magnetically induced voltage in the secondary circuit and the voltage which appears across inductor L. The third and controlling fac-

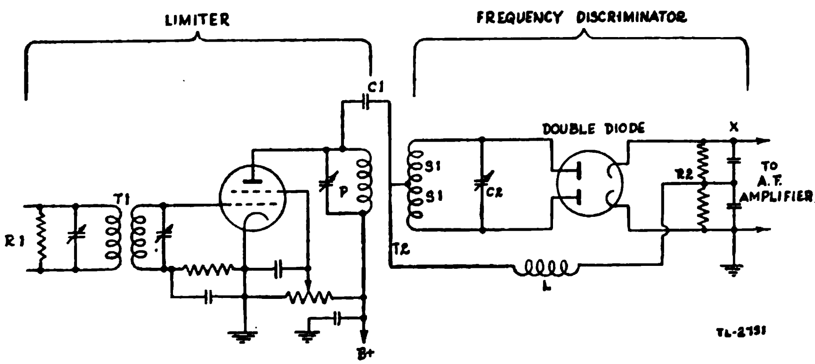


FIGURE 131.—Limiter-discriminator section of f. m. receiver.

tor in the operation of the discriminator is the complex phase relationships between these voltages. These are determined by the relation between the incoming signal frequencies and the resonant frequency of the secondary circuit $S1$–$S2$–$C2$. (See sec. II.)

(2) Suppose the incoming f. m. signal is not modulated; that is, the microphone at the transmitter is idle and the transmitted signal is a steady one of the carrier frequency. Although the mixer action

of a superheterodyne changes the carrier frequency to a lower one, this retains the characteristics of the original carrier, and we can therefore say that the discriminator is being fed an unmodulated signal of one frequency. When the secondary circuit *S*1–*S*2–*C*2 is tuned exactly to this frequency, it shows only a resistive effect to the incoming signal, and the phase relations between the two voltages on each diode are such that no audio frequency variations appear across the output resistor *R*2. In other words, no sound is heard from the receiver.

(3) Suppose now that the microphone at the transmitter is actuated by voice or music. The frequency of the carrier swings accordingly. In the receiver, the secondary tuned circuit *S*1–*S*2–*C*2 is not resonant to the higher and lower frequencies represented by the modulation. At frequencies above resonance, the circuit presents an inductive effect; below resonance, a capacitive effect. The phase relations between the voltages impressed on the diodes shift in such a manner as to unbalance the diode outputs. This unbalance occurs at the audio frequency rate at which the frequency of the incoming signal is changing with modulation. The alternating voltages that develop between point *X* and ground have the same wave shape as the original audio modulating voltage at the transmitter, so the audio amplifier and its associated loud speaker or earphones reproduce an audible sound corresponding to that impressed on the transmitting microphone.

83. General consideration in frequency modulation.—*a*. Frequency modulation transmitting apparatus, in general, is relatively simple; very little power, almost none, is required to accomplish modulation. Receiving equipment, on the other hand, is somewhat more complicated than in the amplitude-modulated system. Receivers for frequency modulation are essentially superheterodynes of advance design. Special consideration is given the limiter and discriminator portions of the circuits.

b. Frequency modulation is necessarily restricted to very high frequency channels, above 40 megacycles, in order to accommodate any reasonable number of operating stations each requiring an overall spread of from 50 to 150 kilocycles. At these high radio frequencies radio waves behave somewhat like light waves, so that the service area of a transmitter is approximately confined to the "line of sight" range of its antenna. Incidentally, static is generally lower at these high frequencies than it is at the lower communication frequencies.

c. A disadvantage of frequency modulation from a tactical standpoint is the fact that of two stations operating on closely adjacent frequencies, a receiving station normally hears only the stronger one, signals from the weaker station being entirely inaudible in the back-

ground of the stronger one. This particular characteristic is probably a very satisfactory one for broadcast (entertainment) service. However, in the event that the inaudible signal is actually the desired one, a receiving operator has no indication of the presence or absence of the weaker station. For military communication this may be a handicap in some situations. With amplitude modulation the receiving operator experiences at least a heterodyne whistle or an unintelligible background jumble, sufficient response to give positive indication of the presence of a weak operating station, so that the receiving operator can proceed accordingly.

84. Facsimile.—*a.* Facsimile involves the transmission of any intelligence which can be recorded on paper, as, for example, letters, photographs, sketches, and maps. Facsimile differs from television in that facsimile transmits only still subjects such as pictures and printed pages, whereas television deals with living scenes. The problems of the former are much simpler than those of the latter. In fact, perhaps the principal problem of any facsimile scheme is that of obtaining a transmitting medium capable of high fidelity reproduction of audio frequency currents. Just such a medium is provided by a frequency modulation radio system.

b. The facsimile transmitter employs a light and lens arrangement which is such as to illuminate a small spot, about $\frac{1}{100}$ inch in diameter, of the copy being transmitted. Reflected light from the surface of the paper carrying the copy is focused on a photoelectric cell, which responds with a current which is in proportion to the light. The magnitude of this current controls the amplitude of an audio oscillator, which in turn modulates a radio transmitter. A mechanical arrangement shifts the light spot across the paper from side to side, the intensity of the reflected light varying with the degree of the blackness of the copy and modulating the transmitter accordingly. At the end of each line of the paper scanned, the spot is shifted down by one diameter, and a new line is scanned until the complete copy has been exposed.

c. The facsimile receiving system contains a rectifier which operates from the output of an ordinary receiver. The output of the rectifier presents a varying d. c. potential, one side of which is applied to a $\frac{1}{100}$ inch diameter steel stylus. The other side of this potential is applied to a metal drum on which is wrapped a specially treated recording paper. The stylus makes contact with the paper, and the passage of current through the paper causes a chemical coating to be removed, thereby exposing a black spot, the density of which is related to the magnitude of the current flowing. By the use of a small

motor rotating at a predetermined speed, the speed being fixed in accordance with the transmitter scanning rate, the recording stylus is moved across the paper exactly in step with the scanning light of the transmitter.

d. In the transmitter each time the scanning device shifts the light spot to the next line an extremely short low-tone impulse is transmitted. In the receiver as the end of a line is reached, the stylus is shifted to the next line and held there by a stop, and the output of the rectifier is transferred from the stylus to an electromagnet. The next impulse actuates the electromagnet, which releases the stop and permits the recording to continue on the new line in synchronization with the transmitted subject.

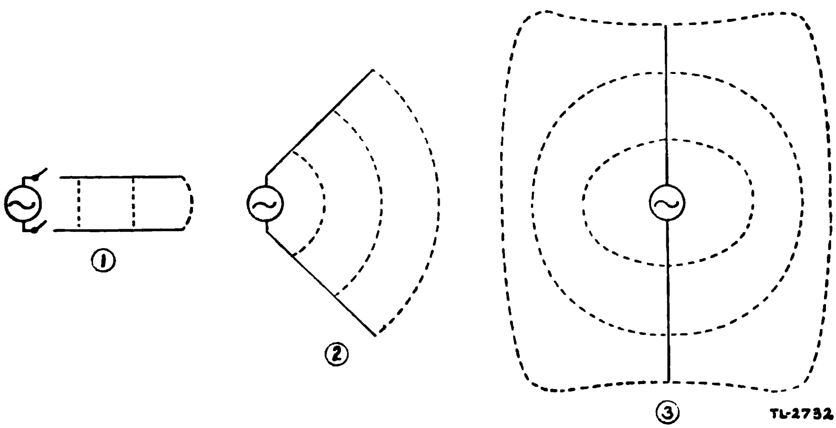
SECTION XIII

ANTENNAS

85. Radiation.—*a.* Two types of electromagnetic field are present about any conductor carrying an alternating current. One is the familiar induction (or magnetic) field, which gives rise to transformer action and to choke coil effects. The induction field falls off rapidly a short distance from the conductor, so that its effects are purely local. The second type of field accompanying an alternating current is a radiation field, which moves off into space. This radiation field may be properly modulated at its source and then intercepted and demodulated by a receiver to convey intelligence from one point in space to another. Some radiant energy is released from conductors carrying currents at the usual 25- and 60-cycle power frequencies; however, the amount is exceedingly small. Highest efficiency radiation is achieved at the higher frequencies, that is, at frequencies normally classified as radio frequencies, 50,000 cycles and above. This accounts for the use of these high frequencies in radio communication.

b. The commonly employed resonant radiating system is essentially a two-wire open-ended transmission line (fig. 132). Energy which flows along the line from the generator is not delivered instantaneously to the far end on the closing of the switch but proceeds

along the line at a finite rate, which rate depends on the frequency of the generated voltage and on the inherent capacitance and inductance per unit length of the line. For a sine wave generated voltage, sine wave currents and voltages occur at each point along the line with a phase displacement from the original which is dependent on the distance from the generator. Electrical reflections of the voltage and current waves occur at the far end of the line, so that if the length of the line and the frequency of the generator are in the proper relation, the reflected waves reinforce the advancing waves always exactly in phase to produce large amplitude standing waves of current and voltage along the line. This is the condition of resonance under which the radiated energy is a maximum.



① Parallel wire transmission line.
② Partly opened-out transmission line.
③ Dipole.

FIGURE 132.—Resonant radiating systems.

c. If the velocity of propagation of waves along the parallel wire transmission system is v feet per second, and if the generator frequency is f cycles per second, then the voltage variations at a point which is at a distance $\lambda=\frac{v}{f}$ feet from the generator are just one cycle behind those of the generator. Similarly, at a distance $2\lambda=\frac{2v}{f}$ feet from the generator the voltage variations are exactly two cycles behind those of the generator. The distance λ (Greek letter, "lambda") is the *wave length* of the radiated wave, that is, it is the distance between two points in the wave which differ in phase by one complete cycle. The condition of resonance is obtained when the over-all length of the radiating system is an integral number of half

or quarter wave lengths depending on the particular type of radiating system.

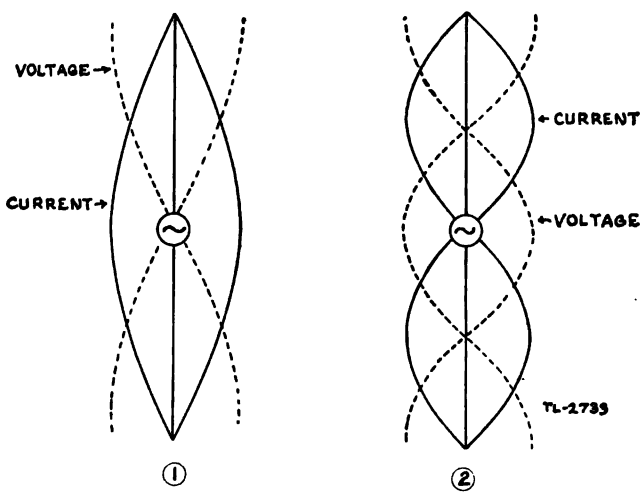
d. (1) It is now the universal practice to designate radio waves in terms of frequency, which is expressed as so many cycles, kilocycles or megacycles. Formerly, waves were designated in terms of wave length, the unit being the meter. Wave length figures are convenient in discussions of antenna systems, as the wave length gives some idea of the actual physical dimensions of the wires. For instance, a "half-wave" antenna for 50-meter transmission is 25 meters (a little more than 25 yards) long.

(2) It is well to remember that an inverse relationship exists between frequency and wave length; high frequencies correspond to short waves, and low frequencies to long waves. The following simple formulas show how one is converted to the other.

$$\text{Frequency (in cycles)} = \frac{300{,}000{,}000}{\text{Wave length (in meters)}}$$

or

$$\text{Wave length (in meters)} = \frac{300{,}000{,}000}{\text{Frequency (in cycles)}}$$



① Fundamental frequency. ② Second harmonic.

FIGURE 133.—Standing waves of current in Hertz antenna. Voltage distribution in dotted lines.

86. Antenna systems.—*a.* The parallel wire antenna confines the moving electric field to one direction and hinders the propagation of waves from progressing generally in all directions. More nearly uniform radiation in all directions is secured as the transmission line

is altered in stages from ① to ③ of figure 132. In ① the radiation field is small in extent and is confined mainly to the end, while in ③ the complete electric field forms a part of the radiation. The disposition of ③ is referred to as an electric dipole or as a Hertz antenna. The standing wave resonance distribution of the current in such an antenna at the fundamental frequency (lowest frequency at which

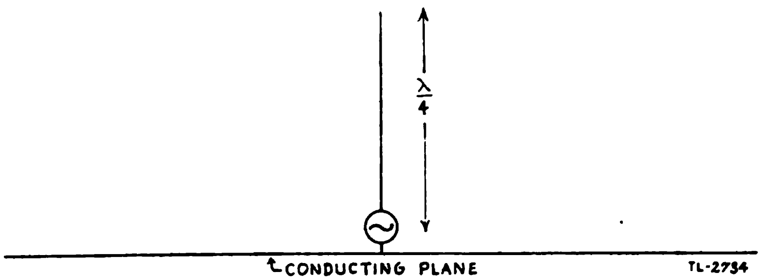
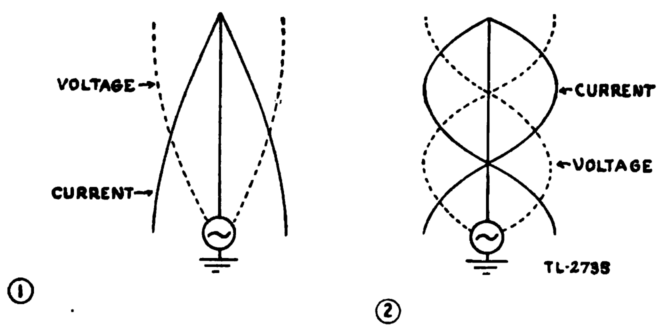


FIGURE 134.—Lower half of Hertz antenna replaced by extensive conducting plane.

the antenna can resonate) is shown in figure 133①, maximum at the center and minimum at the ends. The wave length of the corresponding radiated wave is twice the length of the antenna. Current distribution in the same antenna excited at twice the fundamental frequency (second harmonic) is shown in figure 133②. The wave length of the corresponding radiation is equal to the length of the antenna. The voltage distribution in the dipole is shown by dotted lines in figure 133.



① Fundamental frequency. ② Third harmonic.

FIGURE 135.—Current distribution in Marconi antenna.

b. If the lower half of the antenna is replaced by an extensive conducting plane (fig. 134), no disturbance is caused in the propagated waves from the upper half. A practical form of such a radiating system is the so-called Marconi antenna in which the lower terminal of the generator is connected to ground and the earth's surface serves

as the extended conducting plane. Current and voltage distributions in such an antenna at the fundamental and third harmonic frequencies are as shown in figure 135. The wave length of the radiation at the fundamental frequency is four times the length of the antenna, and at the third harmonic it is four-thirds the length of the antenna. In the grounded Marconi antenna the voltage is necessarily a minimum at the ground, so that the antenna resonates only when excited at odd harmonic frequencies.

87. Feeder systems.—*a.* Standing waves could not arise in a parallel wire transmission line which is infinite in length, because the advancing waves should never reach the far end to produce the necessary reflected waves. As a consequence, since a resonant condition would not be attainable in an infinite line, the radiated energy in such a line would be negligible. Electrically, the condition of an infinite line can be obtained by terminating a finite line in the impedance which a corresponding infinite line can be calculated to present, namely,

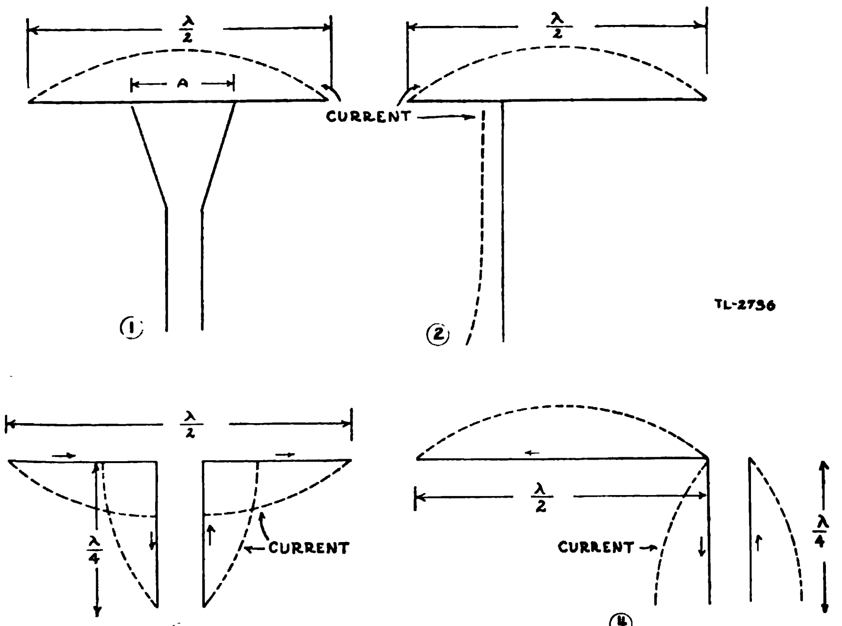
$$Z_o=\sqrt{\frac{L}{C}}$$

where L and C are the inductance and capacitance per unit length of the line, respectively. Z_o is called the characteristic impedance of the line. A transmission line terminated in its characteristic impedance is useful as a feeder system for transferring radio frequency energy without radiative losses from a transmitter to an antenna in case the two are necessarily separated by some distance.

b. Because the effective voltage and current vary along an antenna (figs. 133 and 135), the impedance of an antenna varies according to the positions of the connections used to couple it to the power source. A number of methods are possible for properly coupling a nonresonant line to an antenna. Two of them are shown in figure 136 ① and ②. In the arrangement of figure 136① the appropriate impedance match is secured by varying the spacing, A, between the feeder connections. The single-wire line of figure 136② is a modification of the two-wire line in which the ground supplies a return circuit through the antenna to ground capacitance. The proper adjustment of a nonresonant transmission line can be determined by checking for the absence of current maxima or voltage maxima along the line with an inductively coupled flashlight bulb or with a neon bulb in contact with the wire, respectively.

c. If the transmission line is not terminated in its characteristic impedance, resonance effects result. A resonant transmission line, as

illustrated in figure 136③ and ④, may be regarded as a portion of the antenna which is folded back on itself so that the radiation from one half cancels the out-of-phase radiation from the other half. The line of figure 136③ is fed from the transmitter at a point of low current and high voltage. Such a feed system is commonly connected to the transmitter across the capacitor of a parallel tuned circuit. The line of figure 136④ is fed from the transmitter at a point of high current and low voltage, and is normally connected in series with a series resonant circuit. Resonant transmission lines are less efficient than



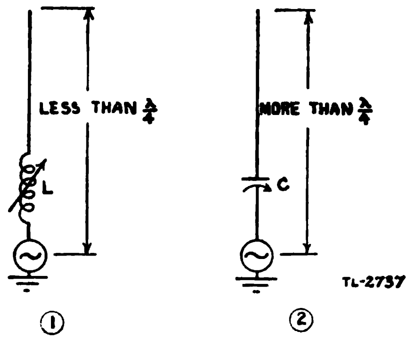
① and ② Nonresonant transmission lines.
③ and ④ Resonant transmission lines.

FIGURE 136.—Feeder systems.

nonresonant lines; however, they are easier to adjust, and they are suitable for use over a wider range of frequencies than are nonresonant lines. Resonant lines are satisfactory if the transmitter is located only a short distance from the antenna.

88. Loading.—*a.* Often one antenna system is used to transmit signals of various frequencies. In most instances it is impractical to vary the physical length of the antenna to resonate accordingly as the excitation frequency is changed. However, the electrical length may be changed by loading, that is, by lumped-impedance tuning.

If the antenna is too short for the wave length being used, it is resonant at a higher frequency than that at which it is being excited. Therefore, it offers a capacitive reactance at the excitation frequency. This capacitive reactance can be counterbalanced by introducing a lumped-inductive reactance as shown in figure 137①. Similarly, if the antenna is too long, it offers an inductive reactance, which can be corrected by introducing a lumped capacitive reactance as in figure 137②.



① To compensate for too short an antenna.
② To compensate for too long an antenna.
FIGURE 137.—Loading.

b. Figure 138 shows a typical antenna tuning unit. In ① the transmitter feeds the antenna system at a point of high voltage; in ② the transmitter feeds the antenna system at a point of high current. The arrangements of ③ and ④ provide antenna loading for use with a short antenna, for example, with a short mast antenna of the buggy whip variety as is conveniently mounted on moving vehicles.

89. Propagation of radio waves.—*a*. The radiation from an antenna is conveniently regarded in two parts, that which travels along the surface of the earth, called the ground wave, and that which is propagated at an angle above the horizontal, called the sky wave. The ground wave suffers energy losses because of earth currents which it induces and because of dielectric effects. The attenuation associated with dielectric losses increases with the frequency, so that the ground wave of high frequency transmitters is effective over only relatively short distances. If the ground wave of a 1-megacycle radiation is effective over about 50 miles, the ground wave of a 10-megacycle radiation from a transmitter of comparable power may be essentially confined to within a 10-mile radius.

b. The sky wave passes into the ionosphere, an ionized layer of the earth's atmosphere, at a height of about 70 miles above the surface

of the earth. The depth of the layer, its degree of ionization, and its effective height above the earth's surface vary with the seasons, solar radiation, and sunspot activity. The radiant energy of a sky wave is partly transmitted through the ionosphere, partly absorbed in it, and partly reflected back to earth. The angle of reflection depends on the frequency and on the angle of approach of the incident radiation. The reflected sky wave is in part reflected back on striking the surface of the earth and continues on its path from earth to ionosphere and back until it is completely absorbed. A picture of the attenuated ground wave and of the refracted and reflected sky waves

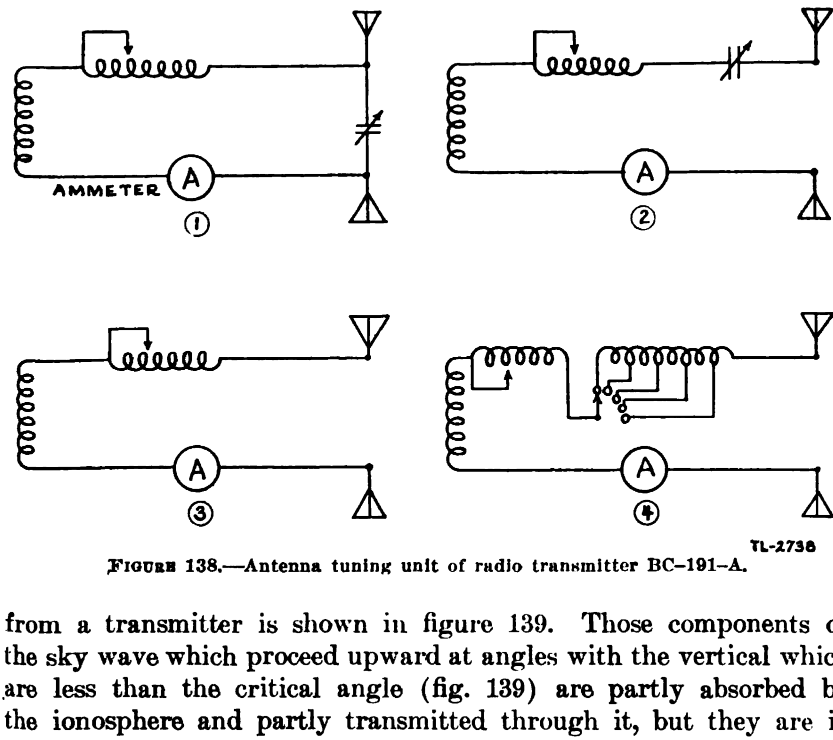


FIGURE 138.—Antenna tuning unit of radio transmitter BC-191-A.

from a transmitter is shown in figure 139. Those components of the sky wave which proceed upward at angles with the vertical which are less than the critical angle (fig. 139) are partly absorbed by the ionosphere and partly transmitted through it, but they are in no part reflected back to the earth. The critical angle is related to the frequency of the radiation, increasing as the frequency increases, so that sky waves of ultrahigh frequency are not returned to the earth at all, and communication on these frequencies is almost entirely by means of the ground wave alone.

c. There is a portion of the earth's surface, as shown in figure 139, which is reached by neither ground wave nor sky wave. The distance from the transmitter to the point where the first sky wave

returns to the earth is called the skip distance. Skip distances of several hundred miles are common on the higher frequencies.

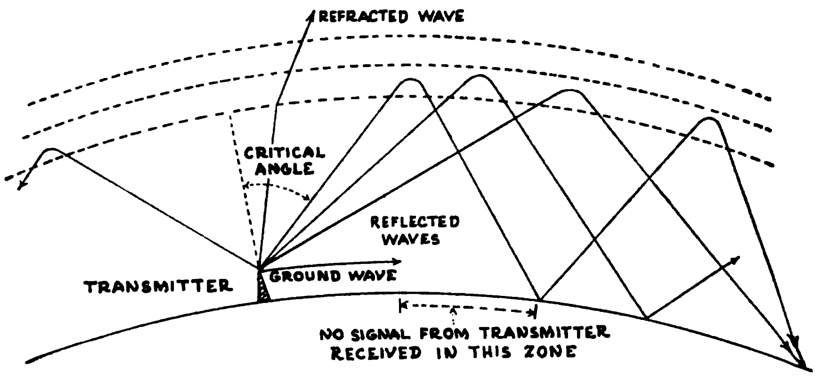


FIGURE 139.—Ground and sky waves from transmitter.

90. Fading.—Fading, random rising and falling of the intensity of a received signal, is attributed to the interaction of different components of the same radiation, which by virtue of having traveled different paths from the transmitter, arrive at the receiver in different phase relations. The condition of the ionosphere is continually changing, so that at one instant the several components of the received wave may be in complete reinforcement to present a very strong signal, and at a later instant the phase relations may be such that the combined effect is very weak.

SECTION XIV

MAJOR COMPONENT PARTS OF RADIO CIRCUITS

91. General.—*a.* In general the theory applicable to electrical communication circuits is the same as that applied to power circuits;

however, the components used in communication circuits differ widely in design from those of power circuits.

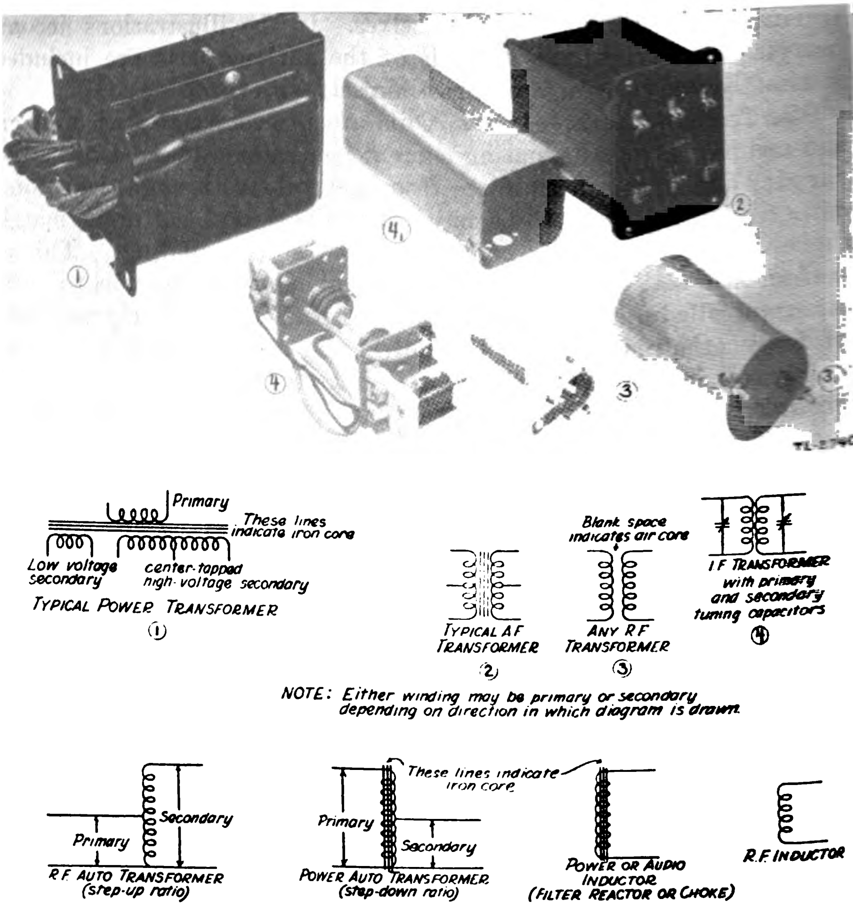
b. Certain convenient "symbols" are universally used in radio diagrams to represent these component parts. In effect they are shorthand pictures of the instruments themselves. In the illustrations accompanying this section, the symbols of the various parts are included so that the student can familiarize himself with them.

92. Transformers.—If two coils are placed near to each other, one coil having an alternating current generator connected to it, the varying lines of magnetic force from one coil cut through the second coil, causing a voltage to be induced in the second coil even though there is no actual metallic connection between the windings. This is transformer action and the two coils in inductive relation to each other are called a transformer. The coil producing the original lines of force is the primary and the coil in which the voltage is induced is the secondary. Transformers used in radio fall into three general groupings as to application. They are power transformers, audio frequency transformers, and radio frequency transformers. The power and audio frequency transformers have cores of magnetic materials (usually some form of iron). The radio frequency transformers are generally of air core design; however, very small magnetic cores (usually powdered iron) are used in some intermediate frequency transformers.

93. Power transformers.—Power transformers in general transfer power from one circuit, at a certain frequency, voltage, and impedance to another circuit at the same frequency, but at a different voltage and impedance. Power transformers used in radio receivers and transmitters transform the source voltage, usually 110–120 volts, 60 cycles, to either higher or lower voltages. When the voltage is raised, for example in plate circuit application, the transformer employed is called a step-up transformer; when the voltage is reduced, for example, in filament circuit application, the transformer employed is called a step-down transformer. Power transformers having both step-up and step-down windings on the same core are widely used in radio receiver and transmitter construction. Figure 140① shows a typical power transformer.

94. Audio frequency transformers.—Audio frequency transformers are used to transfer voltages of wide audio frequency range rather than voltages of a single frequency as in the case of a power transformer. A transformer suitable for transforming voltages in the audio frequency range from one circuit to another must have certain design features not found in a power transformer. A perfect

transformer should transform without loss or phase change as a result of modifying the magnitude of the load impedance. To accomplish this the transformer would need to have unity coupling.



① Multiwinding power transformer. Flexible leads from the various windings are brought out through holes in the bottom of the case.
② Audio amplifying transformer. This particular one is of the push-pull output type, with tapped primary and secondary.
③ Radio frequency transformer. This fits inside the round aluminum shield can (③₁).
④ Intermediate frequency, with attached midget variable air capacitors for tuning the primary and the secondary. This assembly fits inside the square aluminum shield can (④₁).

FIGURE 140.—Typical transformers used in radio circuits.

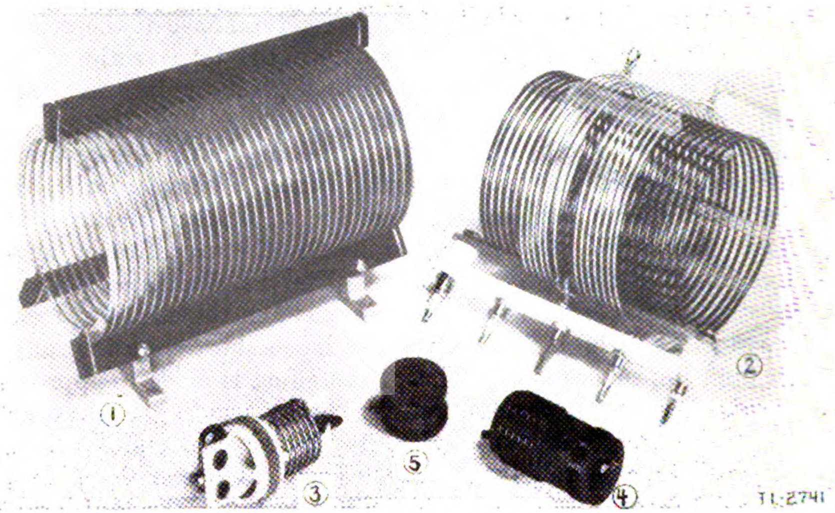
infinite inductance and no resistance in its primary and secondary windings, yet have a finite ratio of winding inductance. A good audio frequency transformer can only approximate these conditions by having the resistance of its windings small and the inductance of its

windings large compared to the circuit with which they are connected, and by having high permeability cores with windings so placed that the flux linkage is a maximum. The frequency response of a transformer is limited at the low frequencies by the inductance of its windings and at the high frequencies by the distributed capacitance of its windings. The core dimensions are determined by the flux required. An audio transformer must be able to carry a limited amount of direct current in its primary winding without causing magnetic saturation of the core. By a suitable compromise of inductance and distributed capacitance, a transformer winding can be designed that will have practically a uniform response to audio frequencies over a wide range. As in a power transformer, the voltage ratio of an audio transformer is equal to the turns ratio of the windings. Figure 140② illustrates a typical audio frequency transformer.

95. Radio frequency transformers.—Radio frequency transformers in receivers and transmitters are used to transfer radio frequency voltages of a comparatively narrow band; therefore, they act as band pass filters. At radio frequencies the transformer again requires additional design precautions. The distributed capacitance of the windings and the associated equipment in the circuit presents a low reactance at high frequencies that has a short-circuiting effect on the high impedance load. Thus, if an effort is made to approach the requirements of a perfect transformer by winding a large coil to obtain a large inductance, the distributed capacitance of the winding will cause parallel resonance. The reactance of the winding might even become capacitive, in which instance the coil would actually act as a capacitor. At radio frequencies, only a comparatively narrow band of frequencies needs uniform amplification, hence the capacitive reactance present can be used in combination with the self-inductance of the windings to obtain resonance and impedances comparable with the R_p of the associated tube. Resonance provides a band pass filter action which passes the wanted frequencies and rejects unwanted frequencies. In practice either one or both of the windings are tuned by variable capacitors of the proper capacitance range to allow tuning across a certain frequency range, for example, 550 to 1500 kc. in the case of a broadcast receiver. The coupling between windings in a radio frequency transformer is rather critical. Loose coupling will cause insufficient voltage transfer and a loss of wanted frequencies; tight or overcoupling will broaden the response or resonance curve and allow unwanted frequencies to pass. The induced voltage in the secondary at optimum coupling is seldom much

higher than the primary voltage; however, there is a resonant rise in voltage in the secondary due to the Q of the resonant circuit. The presence of iron cores at radio frequencies gives rise to eddy current and hysteresis losses that practically preclude their use except in the case of intermediate frequency transformers. Figure 140③ shows a typical radio frequency transformer and ④ shows a typical intermediate frequency transformer.

96. Autotransformers.—It is possible to obtain transformer action with only a single coil if a connection is made somewhere along the winding between the extreme ends. If a step-up voltage



① Single-winding "tank" inductor, used in high power transmitters.
② Plug-in type r. f. transformer used in medium power transmitters.
③ and ④ Small r. f. transformers used in ultrahigh frequency receivers and transmitters.
⑤ Small r. f. inductor or "choke coil" used in receivers and low-power transmitters.

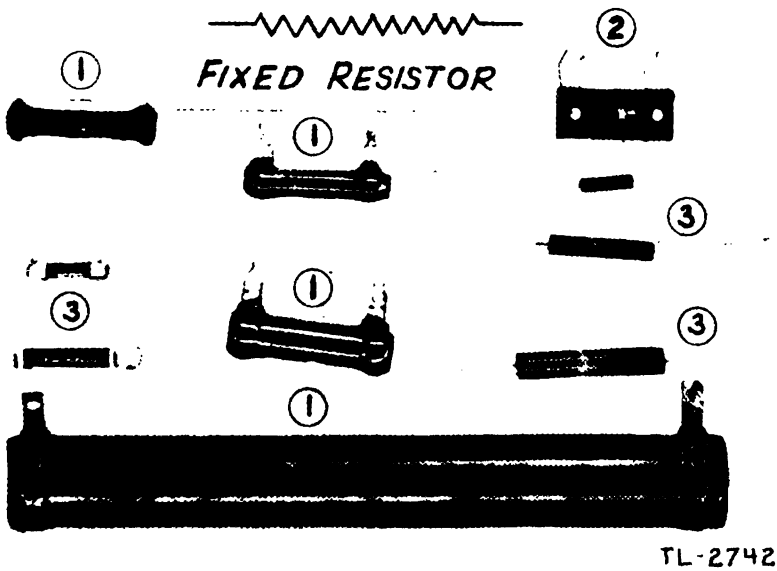
FIGURE 141.—Typical r. f. inductors and transformers.

effect is desired, the winding between the tap and one end is considered the primary and the entire winding acts as the secondary. If a step-down effect is desired, the entire winding is considered the primary and the section between the tap and one end acts as the secondary. Such transformers are known as "autotransformers" and are used in both power and radio frequency applications.

97. Inductors.—An inductor is any single-winding coil. If it has many turns of wire on an iron core, its inductance and therefore its impedance are high, and it is used mainly as part of low frequency filter systems, especially in a. c. power supplies for receivers and

transmitters. Iron core inductors, sometimes called "chokes," resemble power and amplifying transformers in appearance (fig. 140① and ②).

a. Inductors consisting of small air-core spools of wire have a high impedance to radio frequency currents, and are therefore used as chokes in r. f. circuits (fig. 141⑤).



Those in group ① use resistance wire wound on ceramic tubes, with the wire itself covered by a protective coating of heavy enamel. The single resistor ② is also of the wire-wound type, but with a center tap and without covering for the wire. Those in group ③ use a thin layer of metallized carbon on an insulating form, or consist of a solid carbon stick of small cross section.

FIGURE 142.—Typical fixed resistors employed in radio sets.

b. Inductors consisting of a few large turns of heavy wire are used as part of the *LC* "tank" circuits of transmitters. Since they are subjected to high voltages and must carry considerable r. f. current, their insulation must be very good (fig. 141①).

98. Fixed resistors.—Fixed resistors used in radio circuits are of many types and sizes. They range in resistance from a fraction of an ohm to several megohms. Resistors are rated in ohmic value and also according to the power which they can safely dissipate in the form of heat. Figure 142 illustrates typical fixed resistors of various values of resistance and wattage.

99. Variable resistors.—In many instances variable resistors are desirable for obtaining control of current flow in a circuit. There are many types of variable resistors used in radio circuits. Further classified as to application, they fall under the general headings of rheostats, potentiometers, voltage dividers, etc. Figure 143 illustrates these types of variable resistors.

100. Fixed capacitors.—*a.* Both fixed and variable capacitors are used extensively in communication circuits. Fixed capacitors are

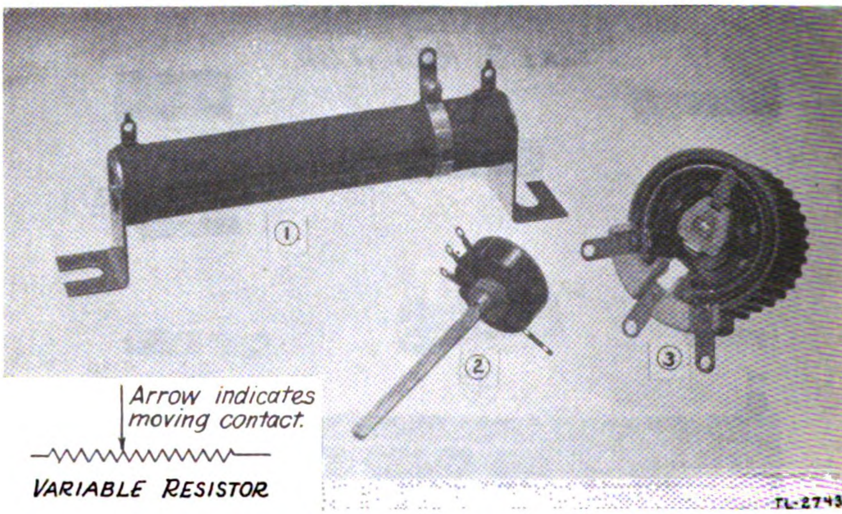
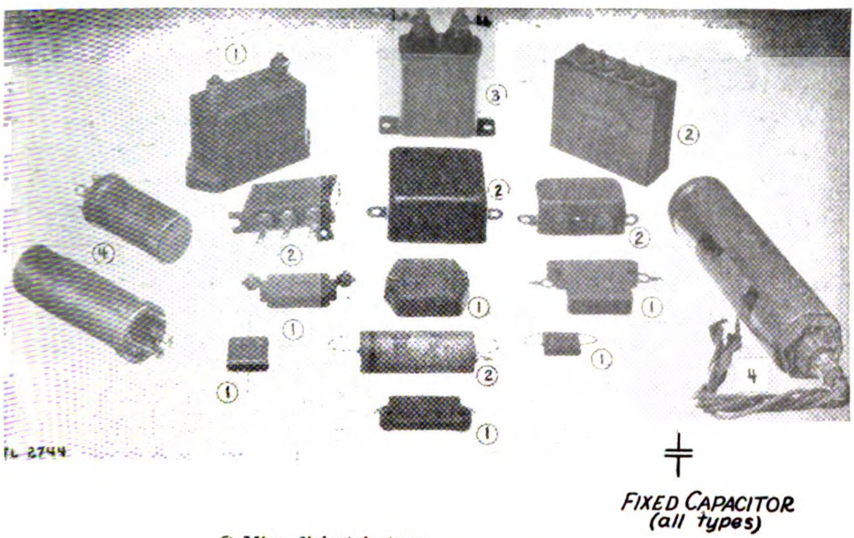


FIGURE 143.—Typical variable resistors used in radio circuits.

of various types and sizes and, in general, are classified in terms of the dielectric used, as mica capacitors, paper capacitors, oil filled capacitors, etc. The electrolytic capacitor uses as a dielectric a thin film of oxide and gas which is formed chemically when voltage is applied to the unit. One of the conductors is usually aluminum foil and the other the electrolyte. Like batteries, electrolytic capacitors are manufactured both in the wet and dry types. Due to the extremely thin film of dielectric, very large values of capacitance without excessive physical size can be obtained. These capacitors have high leakage and low internal resistance as compared to other types and are useful only in pulsating d. c. circuits. Attention must be given to the proper polarity of these capacitors when they are connected in a circuit. Due to these operational limitations electrolytic units are used almost exclusively in power filter circuits.

b. Mica capacitors have low leakage and high voltage ratings but are limited in capacitance by cost factors to about 0.05 microfarad.

Paper capacitors consist of tinfoil and paper rolled together and impregnated with wax to exclude moisture. Capacitors of this type vary approximately in capacitance values from $\frac{1}{10}$ to 2 microfarads. Where large capacitance and high voltage rating are required, oil filled capacitors are used. The actual dielectric material is oil-treated paper, and the whole container is also filled with oil to keep the assembly protected. Figure 144 shows a group of fixed capacitors of various types.



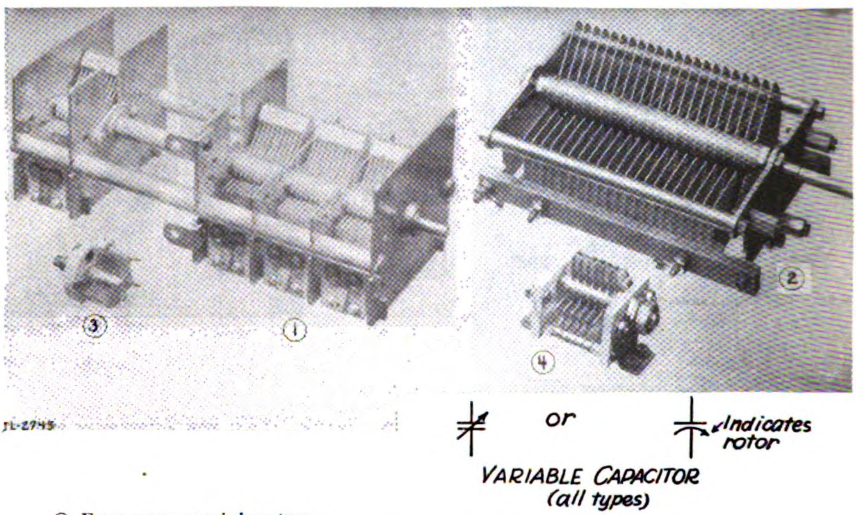
① Mica dielectric type.
② Paper dielectric, wax impregnated.
③ Paper dielectric, oil impregnated.
④ Electrolytic.

FIGURE 144.—Typical fixed capacitors.

101. Variable capacitors.—Most variable capacitors used in communication circuits are of the air dielectric type. In general, they consist of two sets of metal plates insulated from each other and so arranged that one set of plates can be moved in relation to the other set. The stationary plates are called the stator; the movable plates, the rotor. The capacitance range of variable air capacitors is from a few micromicrofarads to several hundred. Figure 145 shows a typical group.

102. Piezoelectric crystals.—Certain crystals, of which quartz is the principal one encountered in radio, exhibit a phenomena called the piezoelectric effect. Prepared sections cut from such a crystal will, when subjected to an electric field, be placed under stress and

slightly deformed. If the crystal section is placed under such mechanical stress, it will develop a difference of potential between its faces. Such a crystal section has a natural frequency of mechanical vibration determined by its position in the original crystal. A crystal section for use in radio is ground to a thickness which will produce a desired frequency, and is mounted in a holder with its faces in contact with metal electrodes. An example of its use is control of frequency in a vacuum tube oscillator circuit. Some of the tuned circuit voltage is fed back to the crystal, causing it to vibrate and



① Four-gang receiving type.
② Single unit, with wide plate spacing, used in high-power transmitters.
③ Midget "trimmer" or "padder" type.
④ Midget type, with wide plate spacing, used in high frequency transmitters.

FIGURE 145.—Typical variable capacitors.

produce a varying potential between its electrodes. This is in turn amplified and impressed on the tuned circuit. Optimum output is obtained by tuning the circuit to the crystal's natural frequency, which is highly stable. The use of crystals in filter circuits has been explained in paragraph 73. Figure 146 illustrates some typical crystals and holders.

103. Microphones.—A microphone is a device for converting acoustical energy into electrical energy. The various types of microphones are named in accordance with the methods used to produce this conversion. Thus, there are carbon, condenser, dynamic, velocity, and crystal microphones. Carbon microphones use the variation of resistance between carbon granules, due to acoustical or

sound pressure on a diaphragm, to vary an electrical current at sound frequencies. Condenser microphones operate on the principle of acoustical energy causing variation in the spacing between two plates; the resulting variation of electrostatic capacitance causes a

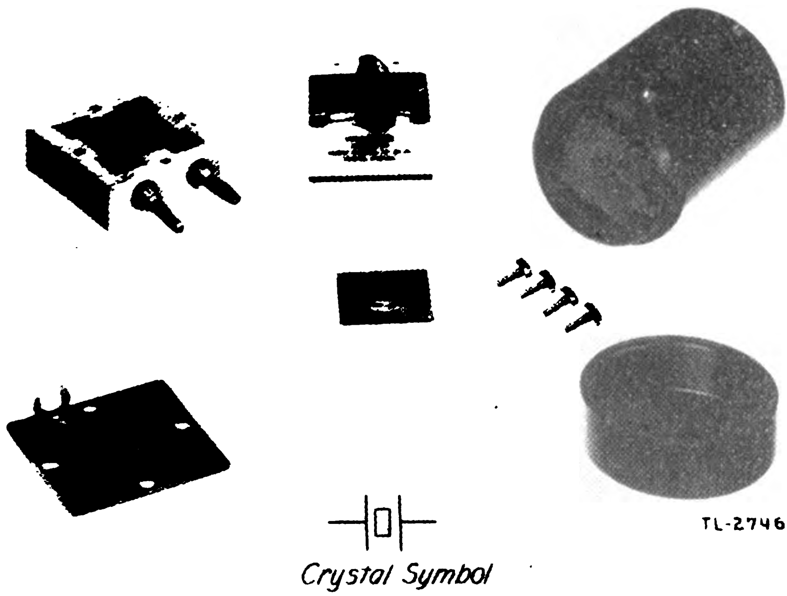


FIGURE 146.—Typical crystals and holders.

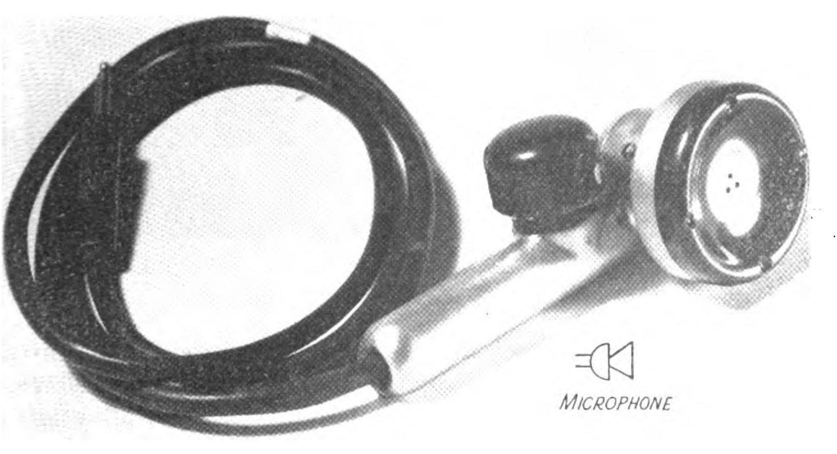


FIGURE 147.—Carbon microphone, T–17.

variation at sound frequencies in a high d. c. potential applied between the plates. A dynamic microphone uses a low-impedance coil mechanically coupled to a diaphragm. The sound waves move the diaphragm and coil, the movement of the coil in a magnetic field

FIGURE 148.—Headset.

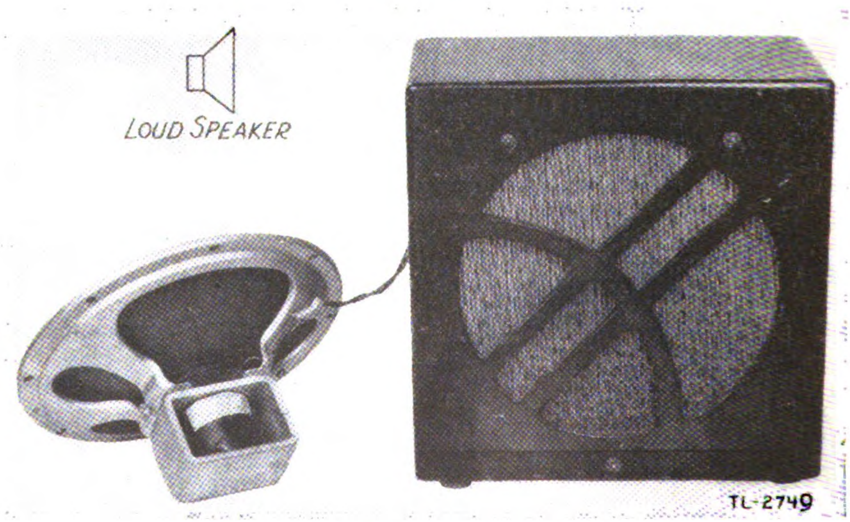


FIGURE 149.—Permanent magnet speaker and cabinet.

inducing currents in the coil at the frequencies of the sound waves. The velocity type or ribbon microphone also operates on the electromagnetic principle but uses a ribbon of dural (a metal alloy) suspended between the poles of a powerful magnet. When the ribbon is vibrated by acoustical energy, it cuts the lines of force and a current,

which varies in accordance with the sound waves, is induced in the ribbon. One type of crystal microphone has a Rochelle salt crystal fastened to a diaphragm. Sound waves move the diaphragm and cause the crystal to vibrate, thus producing an alternating voltage between the crystal electrodes at the frequencies of the sound waves. All of the types mentioned except the crystal microphone require some source of current, magnetic field, or polarizing voltage. Figure 147 shows an Army microphone (type T-17) which is the carbon type.

104. Headsets and loudspeakers.—A headset or a loudspeaker is a device for converting electrical energy into acoustical energy. In general, the headset or loudspeaker performs the opposite function of a microphone. When varying currents flow through the windings on the permanent magnet of a headset, the diaphragm is caused to vibrate in accordance with these currents and produces audible sound waves proportional to the variations of current. Figure 148 shows a typical headset. One type of loudspeaker works on the same principle as the headset. Instead of a metal diaphragm, the speaker uses a paper cone, actuated by an armature, for setting up audible sound waves. Figure 149 shows a loudspeaker of this type removed from its cabinet.

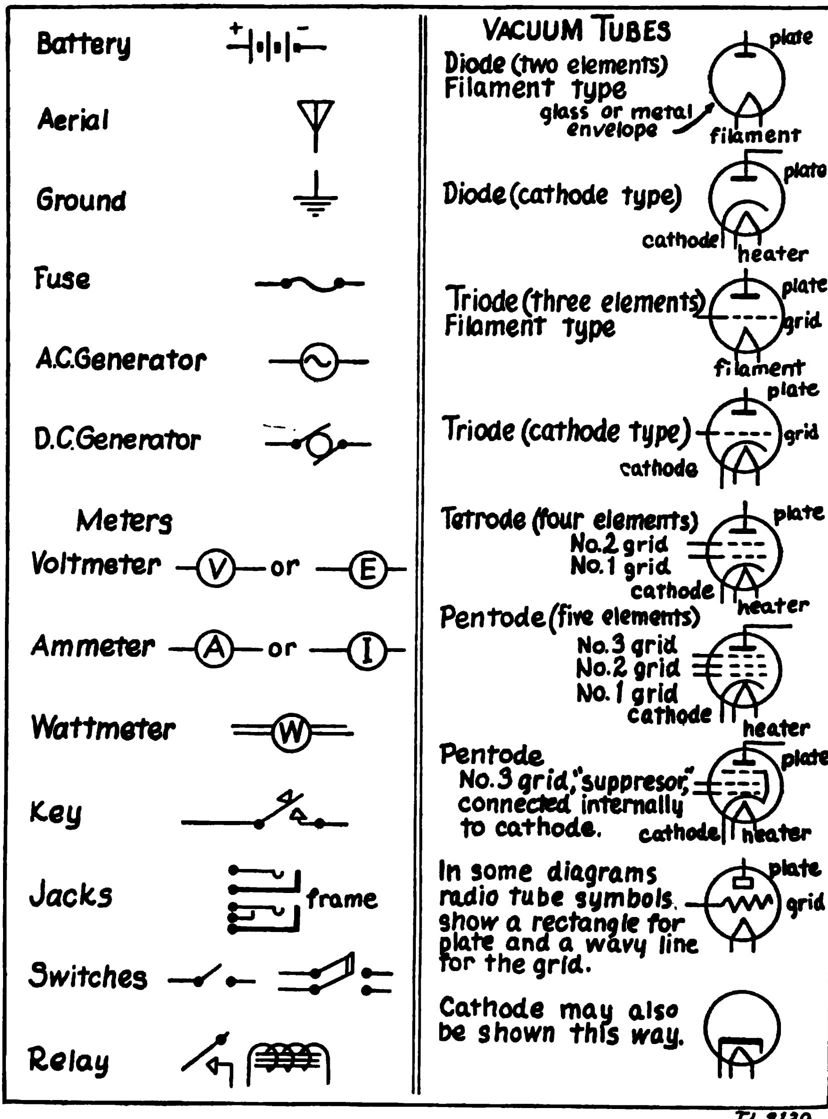


FIGURE 150.—Additional symbols used in radio diagrams.

APPENDIX I

ABBREVIATIONS

The use of certain abbreviations to represent radio words, terms, and expressions, in diagrams and written matter, has become standard. It is well to understand how they are derived and used.

As a general rule, a basic word is abbreviated merely by putting a period after its first letter. Thus w. represents watts and h. represents henrys. If the basic word takes on a prefix to indicate a larger or a smaller unit, the initial letter of the prefix is combined with the initial letter of the word. Thus kilowatt becomes kw. when it is preceded by a number; that is, 10 kw. to mean ten kilowatts. All abbreviations are both singular and plural; the plural form does not take a final s.

The Greek letter μ (pronounced *mū*) stands for micro, meaning one millionth part. It may precede any basic unit of measure. Thus the farad, the measure of capacitance, which is too large for practical purposes, invariably is cut down to the microfarad, one millionth part of a farad. For very small capacitances, the unit micromicrofarad is used. The corresponding abbreviations are μf and $\mu\mu$f.

The letter m as a prefix means one thousandth part. (By itself or as the last letter of an abbreviation it means meter, the unit of length in the metric system.) Milliampere, a thousandth of one ampere, is abbreviated as ma. Small radio frequency inductors (choke coils) usually have values of a few millihenrys, the abbreviation for this unit being mh.

The capital letter M (to be distinguished carefully from the small letter m) is sometimes used for mega, meaning one million. It applies particularly to the term megacycles, one million cycles. Because it is so readily confused with m for milli, it should be avoided, and the word megacycles should be spelled out in full wherever possible.

The Greek letter μ is also used as a general symbol—not as an abbreviation—for the amplification factor of vacuum tubes and for the permeability of magnetic materials. Since it is employed alone in these connections, it is not likely to be mistaken for the prefix μ meaning one millionth.

The student who reads books and current magazines will quickly notice certain very confusing irregularities in the use of the prefix letters μ and m. In many cases m is employed instead of μ to indi-

cate one millionth, and in the same text it is also used to mean one thousandth. The abbreviation mf. (also frequently given as mfd.) correctly means millifarad, but capacitors having values in millifarads would be enormous. (The largest capacitors used in radio work are about 50 microfarads.) Actually, the "mf." is intended to mean μf., microfarads, and it is fairly safe to assume that this is the case. However, when the letter m is used before a. for ampere or v. for volts, the abbreviations are quite likely to mean milliampere or microampere, or millivolt or microvolt, respectively, unless the circuit conditions, the nature of the apparatus, etc., give some indication of what unit is intended. To avoid this trouble, publications of certain engineering societies use no abbreviations at all, but spell out all words and terms. This is a safe and sensible practice, but it is often desirable or even necessary to employ the shortened forms, and the following list is therefore given as a matter of information and reference. The abbreviations are grouped according to their common usage, rather than alphabetically.

Abbreviation	*Meaning*
a	ampere
μa	microampere (one-millionth of an ampere)
ma	milliampere (one-thousandth of an ampere)
v	volt
μv	microvolt (one-millionth of a volt)
mv	millivolt (one-thousandth of a volt)
kv	kilovolt (one thousand volts)
kva	kilovolt-ampere
w	watt
μw	microwatt (one-millionth of a watt)
mw	milliwatt (one-thousandth of a watt)
kw	kilowatt (one thousand watts)
ohm	Not abbreviated. Spell out in full or use the Greek letter omega (Ω).

Abbreviation	*Meaning*
Greek letter omega Ω (capital) ω (small letter)	The Greek letter omega is the equivalent of the letter o, so it is frequently used in diagrams to indicate resistance values in ohms. The capital omega should always be used because the small letter looks like an ordinary w and can easily be confused with w for watt.
MΩ	megohm (mega plus ohm), meaning one million ohms.
c	cycle
kc	kilocycle (one thousand cycles)
mc	megacycle (one million cycles)
f	farad
μf	microfarad (one-millionth of a farad)
μμf	micromicrofarad
h	henry
μh	microhenry (one-millionth of a henry)
mh	millihenry (one-thousandth of a henry)
m	meter (measure of length)
cm	centimeter (one-hundredth of a meter)
mm	millimeter (one-thousandth of a meter)
L, C, R	These are used as symbols rather than as abbreviations for inductance (L), capacitance (C), and resistance (R), in formulas and diagrams. Thus, the inductors in a circuit usually are marked L1, L2, L3, etc.; the capacitors C1, C2, C3, etc.; and the resistors R1, R2, R3, etc.

Abbreviation	*Meaning*
I or i, E or e	Similarly used as symbols to represent current (I or i) and voltage (E or e). Thus, I_p, used in discussions of tube characteristics, means plate current; E_g means grid voltage.
K or k	Used alone near tube symbols, represents the cathode connections.
H or h	Used alone near tube symbols, represents the filament or heater connections.
G or g	grid
P or p	plate
c. w.	continuous wave (refers to keyed, unmodulated radiotelegraph signals)
i. c. w.	interrupted continuous wave (keyed "tone" radiotelegraph signals)
r. f.	radio frequency
t. r. f.	tuned radio frequency
a. f.	audio frequency
i. f.	intermediate frequency
r. f. t.	radio frequency transformer
a. f. t.	audio frequency transformer
i. f. t.	intermediate frequency transformer
d. c.	direct current
a. c.	alternating current. ("D. c. current" and "a. c. current" are incorrect usage)
h. f.	high frequency
u. h. f.	ultra high frequency
b. f.	beat frequency
b. f. o.	beat frequency oscillator
a. m.	amplitude modulation
f. m.	frequency modulation
a. v. c.	automatic volume control
d. a. v. c.	delayed automatic volume control

Abbreviation	*Meaning*
a. v. e.	automatic volume expander
ant	antenna
gnd	ground
xtal	crystal
c. r.	cathode ray
SW	switch
s. p. s. t.	single pole single throw (refers to switches)
d. p. d. t.	double pole double throw
d. p. s. t. (etc.)	double pole single throw
d. c. c.	double cotton covered (refers to wire insulation)
s. s. c.	single silk covered
s. c. c. (etc.)	single cotton covered
c. p. s.	cycles per second
r. p. m.	revolutions per minute
hp	horsepower
r. m. s.	root mean square
"mike"	microphone
"A" "B" "C"	Refers to power supplies to the filament ("A"), plate ("B"), and grid ("C") circuits of radio tubes. Originally meant to designate batteries (storage or dry type) but now used in a general sense.
e. c. o.	electron coupled oscillator
v. t. v. m.	vacuum-tube voltmeter
WVP, WAR (etc.)	Call signs of radio stations are all capitals, without periods.
C F	Centigrade Fahrenheit — Temperature scales. When not otherwise indicated, readings in degrees are assumed to be on the Fahrenheit scale.

Appendix II

BIBLIOGRAPHY

The following books are recommended for general study:

ELECTRICITY AND MAGNETISM

TM 1-455, "Electrical Fundamentals." This is an Army publication.

RADIO PRINCIPLES

"Radio Physics Course," by Alfred A. Ghirardi. Radio Technical Publishing Company, New York, N. Y.

"Frequency Modulation," by John F. Rider. John F. Rider Publisher, Inc., New York, N. Y.

"Fundamentals of Radio," by F. E. Terman. McGraw Hill Book Company, New York, N. Y.

"The Radio Handbook," Editors and Engineers, Ltd., Santa Barbara, Calif.

"The Radio Amateur's Handbook," American Radio Relay League, West Hartford, Conn.

VACUUM TUBE DATA

"Receiving Tube Manual."

"Transmitting Tube Manual," both published by RCA Manufacturing Company, Inc., Camden, N. J.

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[A. G. 062.11 (2-21-41).]

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G. C. MARSHALL,
Chief of Staff.

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D 1, 2, 7, 17 (3); B (2); R 1–7, 17 (5); Bn 3, 4, 17 (5), 1, 11 (10); IBn 2, 5–7 (5); IC 1 (3), 2–7 (10), 11, 17 (15).
(For explanation of symbols, see FM 21–6.)

U. S. GOVERNMENT PRINTING OFFICE: 1941

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - Price 25 cents

TM 11-456

WAR DEPARTMENT

TECHNICAL MANUAL

WIRE TELEGRAPHY

July, 15, 1942

TECHNICAL MANUAL

WIRE TELEGRAPHY

CHANGES No. 1 }

WAR DEPARTMENT,
WASHINGTON 25, D. C., 1 April 1944.

TM 11-456, 15 July 1942, is changed as follows:

33. 215-Type Western Electric relay.

* * * * * * *

b. Flux.—Due to the permanent magnet, lines of force flow as shown by the solid arrows. No flux flows * * * the dotted arrows. This flux in the reed aids the flux in the right pole piece and opposes that in the left. The reed thus * * * different winding arrangements.

* * * * * * *

47. The M–15 teletypewriter.

* * * * * * *

e. Send-Receive-Break key.—The SEND-RECEIVE-BREAK key * * * a distant station. The send-receive switch on all other machines in the circuit will be thrown to the receive position automatically when a break is transmitted or two successive "blank" key signals are received. It must be * * * order to transmit.

* * * * * * *

59. Power supplies.—If an external * * * to 60 milliamperes. The current may vary materially from this value and still maintain satisfactory operation when using line relays for the receiving magnets. The permissible current * * * with each teletypewriter.

APPENDIX I (SUPERSEDED)

INDEX TO TECHNICAL AND FIELD MANUALS

(See FM 21–6 for complete list)

TM 11–302	Charging Set SCR–169
TM 11–330	Switchboards BD–71, BD–72, BD–72–A and BD–72–B
TM 11–331	Switchboard BD–14
TM 11–332	Telephone Central Office Set TC–4
TM 11–333	Telephones EE–8–A, EE–8–B, and EE–8
TM 11–335	Telephone Central Office Set TC–1
TM 11–340	Telephone Central Office Set TC–2

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TM 11-345	Cabinet BE-70-( ) (Wire Chief's Testing)
TM 11-351	Telegraph Sets TG-5, TG-5-A, and TG-5-B
TM 11-353	Installation and Maintenance of Telegraph Printer Equipment
TM 11-354	Telegraph Printer (Teletypewriter) Sets EE-97 and EE-98; Teletypewriter Sets EE-97-A, EE-98-A and EE-102
TM 11-355	Telegraph Terminal CF-2-A (Carrier)
TM 11-358	Telephone Central Office Set TC-3.
TM 11-359	Line Unit BE-77-A and Line Unit BE-77
TM 11-360	Reel Units RL-26 and RL-26-A
TM 11-361	Test Sets EE-65 and EE-65-A through -F
TM 11-362	Reel Unit RL-31
TM 11-363	Pole Line Construction
TM 11-430	Storage Batteries for Signal Communication Except Those Pertaining to Aircraft
TM 11-431	Target Range Communication Systems
TM 11-457	Local-Battery Telephone Equipment
TM 11-458	Common-Battery Telephone Equipment
TM 11-462	Reference Data
TM 11-900	Power Units PE-75-C through PE-75-T
TM 11-903	Power Unit PE-77-(*)
TM 11-957	Rectifier RA-87
TM 11-2003	Carrier Hybrid CF-7
TM 11-2004	Repeater Set TC-18 (Terminal)
TM 11-2005	Repeater Set TC-19 (Intermediate)
TM 11-2200	Bias Meter I-97-A
FM 1-45	Signal Communication; Army Air Forces
FM 5-10	Construction and Routes of Communication; Engineer
FM 11-5	Missions, Functions, and Signal Communication in General; Signal Corps
FM 24-5	Signal Communication

[A. G. 300.7 (27 Mar 44).]

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WAR DEPARTMENT, WASHINGTON, July 15, 1942

WIRE TELEGRAPHY

SECTION I

SINGLE-LINE TELEGRAPHY

1. General.—*a. Importance.*—The importance of telegraphy to military communication can hardly be over-estimated. It is more rapid, reliable, and exact than any other method of electrical transmission of messages. The telegraph operator can work over a poor line at speeds which the radio operator cannot maintain. There is usually no delay for encoding and decoding of messages sent by telegraph. When static makes radio transmission difficult or impossible, the telegraph is unaffected. A few pounds of equipment will put a telegraph channel into operation over wires that must be laid to provide telephone communication. These advantages are often overlooked by the communication officer.

b. Scope.—This text proposes to give only a very elementary explanation of the telegraph apparatus and methods which are of interest to communication officers. Single-line telegraphy, which will be discussed in succeeding paragraphs, has a wide military application and is also the basis on which other systems are developed. It be may defined as telegraphy in which operation in both directions may be effected but not at the same time.

2. Sounder.—The sounder is the instrument from which the signal is read, and is illustrated in figure 1. As can be seen from the figure, it consists of an electromagnet of two coils and an armature which is held away from the coils by the spring pushing against the

sounding bar to which the armature is attached. When a current flows through the coils of the electromagnet, the armature is attracted and moved downward; a set screw in the right hand end of the sounding bar strikes the frame beneath it, giving a click. The armature remains down until the coils are no longer energized, then the spring forces the pivoted sounding bar up. The latter strikes the upper set screw, giving another click. Due to the construction of the apparatus the two clicks are dissimilar in sound; the interval between them determines by its length whether the character is a dot or a dash. For satisfactory operation, the sounder should be adjusted so that, when the armature is in the operated position, it is as close as practicable to the pole pieces without actually touching them. This clearance can be set by

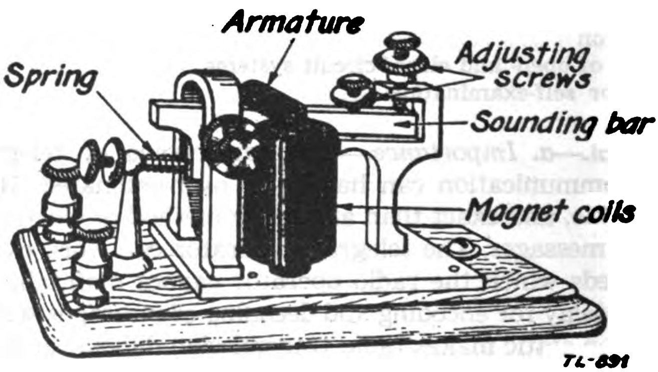


FIGURE 1.—Telegraph sounder.

means of the adjusting screw on the sounding bar, using a sheet of writing paper as a thickness gage. The travel of the sounder bar is usually set at about $\frac{1}{16}$ of an inch. This setting is made by means of the adjusting screw on the sounder frame, after the proper armature clearance has been set. The tension of the sounder spring is adjusted so that the sounder operates satisfactorily and produces the type of sound desired by the operator. After the sounder is properly adjusted, all lock nuts must be securely tightened, or the sounder will vibrate out of adjustment in a few minutes of use.

3. Circuits.—*a. Closed-circuit system.*—It is obvious that if a sounder were placed in a circuit such as shown in figure 2, an operator could send a message by operating the key and thus actuating the sounder.

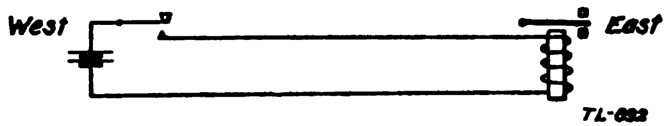


FIGURE 2.—One-way closed-circuit telegraph system.

It can also be seen that with this circuit there is only one-way transmission, that is, East cannot send any message to West. To get two-way transmission, a key and a sounder are used at each end, as in figure 3.

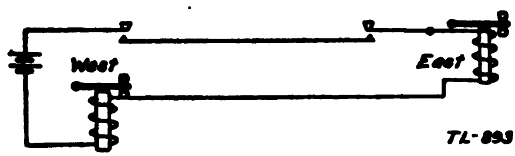


FIGURE 3.—Two-way closed-circuit telegraph system.

In figure 3, it is apparent that, since the circuit is broken in two places, one operator must hold his key closed while the other sends. To overcome this difficulty a short-circuiting switch is placed at each key, by means of which the operator closes the line when he is not sending. (See fig. 4.)

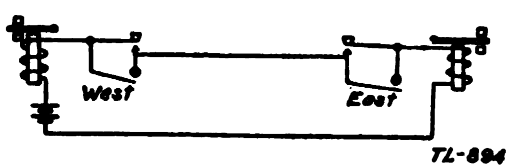


FIGURE 4.—Two-way closed-circuit system with short-circuiting switch.

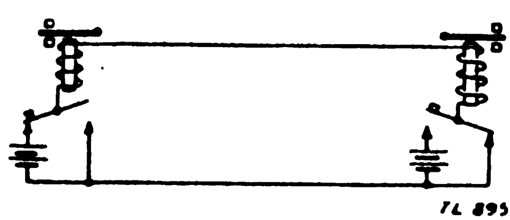


FIGURE 5.—Open-circuit telegraph system.

When neither operator is sending, the circuit is closed and current is flowing. This system is called the closed-circuit system and is the one in common commercial use in the United States. Another system, in general use elsewhere, is the open-circuit system, which is illustrated in figure 5.

b. Open-circuit system.—The differences between the two systems should be noted. The closed-circuit system requires the use of a key with only a single contact; The open-circuit system key has a front and a back contact, the key being held closed on the

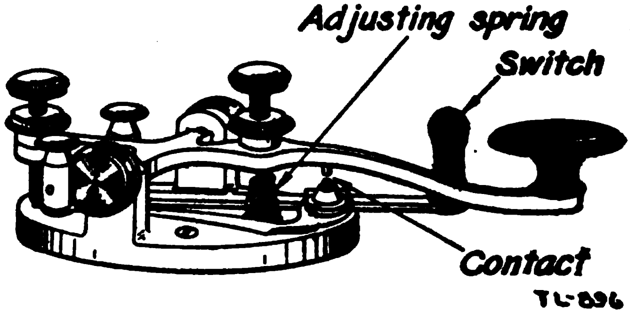


FIGURE 6a.—Closed-circuit telegraph key.

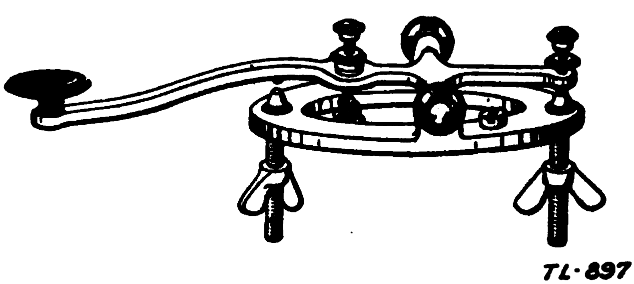


FIGURE 6b.—Open-circuit telegraph key.

back contact by a spring when the operator is not sending. The closed-circuit system uses only one battery; the open-circuit system must have at each station enough battery to operate the entire circuit. In the closed-circuit system, current flows in the line at all times except while spacing between the dots and dashes and between characters. In the open-circuit system, current flows only while dots and dashes are being made. These are the principal differences; the advantages and disadvantages of each will be

discussed later. In figures 6a and 6b are shown the closed- and open-circuit types of key.

c. Ground-return circuit.—Return to a consideration of the closed-circuit system and consider the modification which must be made in the circuit of figure 4 in order to make it more efficient and economical. First of all, wire may be saved by using a ground return, that is, by making the earth serve as one conductor of the circuit. The ground-return circuit will also reduce maintenance and will have a lower resistance than will a complete metallic circuit, if low resistance grounds are obtained. This is of importance because it means that a smaller voltage will be required to produce the minimum current necessary to operate the system. The ground-return has certain inherent disadvantages, the chief of which are:

(1) Contrary to the assumption often made, the earth is not everywhere at the same potential; there are actually considerable differences of potential between different points on the earth's surface. Such a difference of potential may oppose the battery which is driving current through a circuit, and thus require the use of additional battery to neutralize its effect.

(2) Induction from neighboring power circuits is greater for a ground-return circuit than for a metallic-return circuit, since on a properly transposed metallic circuit the same voltage is induced in each of the two conductors.

(3) The ground-return circuit is more susceptible to earth-current disturbances accompanying the Aurora Borealis than is the all-metallic circuit.

(4) In Army field telegraph systems, the ground-return circuit is more susceptible to interception by the enemy.

(5) The use of the ground-return requires that a ground be made at each terminal station. This must be a good ground; that is, one of low resistance. Methods of obtaining grounds are discussed in section III.

In general, it may be said that the advantages of the ground-return circuit outweigh its disadvantages for army use.

d. Relays.—(1) The next modification to be made in the circuit under development is made by the characteristics of the sounder. To make readable signals, the sounder must give sharp distinct clicks. Therefore the magnetic field of the coils must be strong. This strong field might be developed in either of two ways; by means of a large current flowing through a few turns or a small

current flowing through many turns. The latter method is the one chosen, since it is less wasteful of energy. The sounder operates most satisfactorily when the current through its coils is always the same. But the current in a telegraph line may vary widely due to various conditions, chief of which is weather.

(2) Operation is improved by removing the sounder from the circuit and by putting in its place an electromagnetic device called a relay. The relay has an armature which is held away from the coils by a spring; current in its coils pulls up the armature. The sounder is connected in series with a battery, the relay armature and a contact which the relay armature strikes when pulled up. Current in the coils of the relay pulls up the relay armature, and the relay armature, striking its front contact, closes the sounder circuit. Closing the sounder circuit energizes the sounder coils and pulls down the sounding bar. When the main line circuit is broken, the relay armature falls back under the action of its spring and opens the sounder circuit; the sounding bar is then pulled up by the spring of the sounder.

(3) The modified circuit is shown in figure 7. The circuit consisting of the battery, sounder, relay armature and the armature contact is called the local circuit; the circuit containing the relay, key, battery, line, and ground is called the main line. The relay is pictured in figure 8. The relay has the advantage that is requires

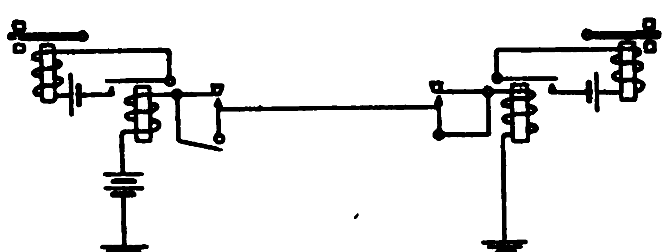


FIGURE 7.—Closed-circuit system with relays.

only a small current to operate it. The relay does not have to make any click; it has only to close the local circuit. It is immaterial whether or not the relay strikes its contact with definite force; so long as it strikes the contact at all, the local circuit will be closed, and the sounder gives the same click regardless of line conditions. Several adjustments are provided on this type of relay. First, the armature stop should be adjusted so that when the armature rests against the stop, the armature will be perpendicular to the in-

strument base. The armature contact should then be adjusted to reduce the armature travel to the minimum necessary to interrupt

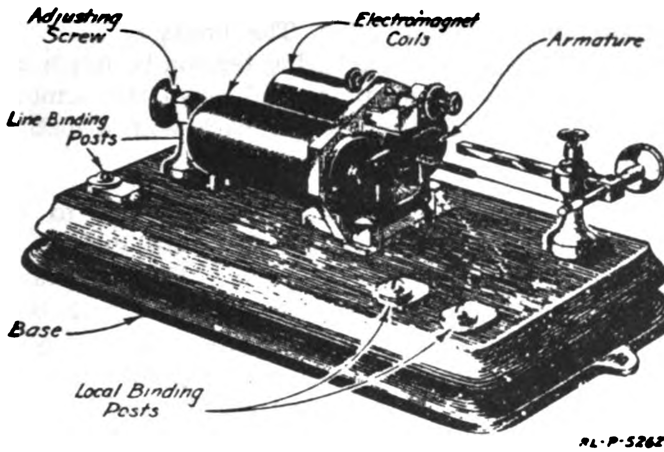


FIGURE 8.—Telegraph relay.

the line current. This motion will normally be of the order of 1/32 inch or less. The armature spring should then be adjusted, with the relay in position in which it is to operate, to exert just sufficient tension to retain the armature against the armature stop when no current is flowing. Further adjustment of this spring is seldom required. Under no circumstances is it ever necessary to exert great tension with this spring. These preliminary adjustments having been made, the relay is ready to be connected into a circuit. The operation of the relay in the circuit is adjusted by means of a large adjusting screw on the ends of the coils opposite the armature. Operating this screw changes the position of the coils mechanically with respect to the armature and provides sufficient flexibility for practically all purposes.

(4) The following information regarding relays and sounders should be noted.

Instrument	Resistance	Normal Operating Current
Main-line relay	75 ohms	80 milliamperes
Main-line relay	150 ohms	40 milliamperes
Main-line relay	250 ohms	25 milliamperes
Local sounder	4 ohms	250 milliamperes
Local sounder	20 ohms	175 milliamperes
Main-line sounder	150 ohms	40 milliamperes

Of these the 150-ohm relay and the 20-ohm sounder are the most commonly used. The normal operating current is the one sought. Actually, a relay will operate with currents considerably larger or smaller than this particular value. The limits of operation of a sounder are narrower, for if the spring tension be much decreased in order to allow a less current to pull down the armature, the spring will not bring the sounding bar back with a distinct click.

4. Leakage.—*a. General.*—The modification next to be made requires an understanding of leakage from the line. In practice, the insulation between lines is never perfect. High resistance paths exist between the lines at each cross arm, the path being over the insulators and the cross arm. In a ground return system, the path at each pole is over the insulator, along the cross arm, and down the pole to ground. In wet weather, the resistance of these paths is greatly lessened and may be only a small fraction of its dry weather value. All of these paths are in parallel, and their joint resistance is the resistance of one divided by the number of paths. Fortunately we need not consider the effect of each of these paths in turn because it may be proved mathematically that a line having uniform leakage may be replaced by a line having a concentrated leakage resistance at the middle, and that the currents at the two ends of this line will be the same as for the line which was replaced. The leakage of a telegraph line is not uniform, since it occurs only at poles, but it is nearly enough so to permit the use of this treatment with a high degree of accuracy.

b. Example.—Such a line is shown in figure 9, and the currents under different conditions may be computed as follows:

(1) *West sending.*—When West's key is open, no current flows through either relay. When West closes his key, the current through West's relay is 50 milliamperes and the current through East's relay is 40 milliamperes.

(2) *East sending.*—When East's key is open and West's switch is closed, no current flows through East's relay but there is a path through West's relay out over the line to the leakage resistance, down through the leakage resistance to ground and back to battery. Eighteen milliamperes flow through this path when East's key is open. When East closes his key, the currents are as in the

preceding paragraph, 40 milliamperes through East's relay and 50 milliamperes through West's relay.

5. Working margin.—*a. Definition.*—The difference between the current in a receiving instrument, when the distant operator's key is marking and when it is spacing, is called the working margin.

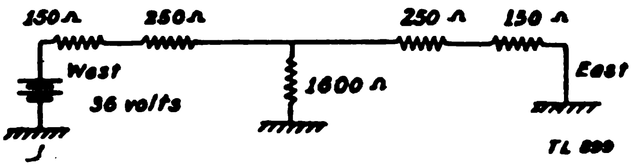


FIGURE 9.—Closed-circuit system with single battery, showing leakage.

In the closed-circuit system, a key is spacing when it is open and marking when it is closed. In the open-circuit system, the back contact of the key is made for spacing and the front for marking.

b. Examples.—(1) *Single battery.*—With the circuit of figure 9, East has a working margin of 40 milliamperes but West has one of only 32 milliamperes. The circuit is meant to work both ways and obviously it is not working equally well both ways. Had it been wet weather and the leakage resistance cut down to, say 400 ohms, East's working margin would have been 30 milliamperes (30−0=30) but West's would have been 15 milliamperes (60−45=15). Under such conditions, East could receive very satisfactorily but West might have difficulty in adjusting his relay to pull up on 60 milliamperes and release on 45 milliamperes. Seventeen milliamperes is considered by many as the lowest satisfactory working margin for the type relay which has been discussed.

(2) *Divided battery.*—The following happens when the battery is divided as in figure 10. (The leakage resistance of 400 ohms has been assumed since it was the critical value in the case discussed above.) When either key is closed with the key at the opposite end open, current flows through the relay at the closed key end. In figure 10, this current will be 22.5 milliamperes. When both keys are closed the current will be the same through each relay, 45

milliamperes. (This result may be arrived at either by the use of Kirchoff's laws or by noting that the midpoint of the line is at ground potential since half of the battery is at either end.) With the circuit shown in figure 10, both operators have the same working margin and this working margin is 50 percent greater for West

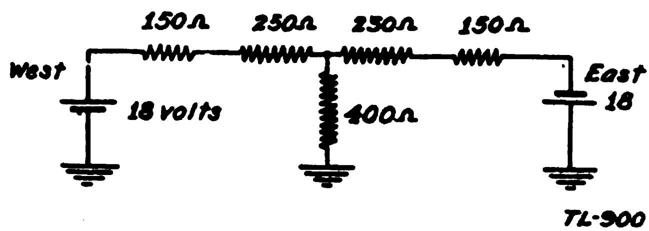


FIGURE 10.—Closed-circuit system with divided battery, showing leakage.

than it was with the hookup of figure 9. Reception is still good for East and it has been greatly improved for West.

6. **Complete circuit.**—The preceding example makes clear the modification necessary in the circuit of figure 7; the modified circuit appears in figure 11. In the latter figure, a milliammeter has been added at each end to enable the operator to read the current which flows through his relay when the distant key is opened and closed, thus learning his working margin.

7. **Power source.**—*a. Means.*—In all of the preceding diagrams, battery has been shown as the source of power; a direct-current generator or suitable rectifier operating on commercial alternating current, and producing suitable values of direct current, would have served equally well. These latter are used where sufficient power is needed to justify its installation, otherwise battery is more suitable.

b. Voltage.—The resistance of lines will obviously vary with their length, and a specific voltage is necessary for each to give the proper operating current. It would require a separate battery for each line if the voltage were fitted to the line; it is more economical to have one or more power supplies and to cut the voltage furnished by them down to the requirements of an individual line by inserting resistance between the power supply and the line. Thus one power supply may be used to serve several lines, each requiring a different voltage.

c. Protective resistors.—Aside from the resistances used as just explained, a resistance is connected in series with each power supply to prevent damage to it in case of short circuit within the office itself or at the switchboard. The resistance so used is 2 or 3 ohms per volt of output.

d. Protection from extraneous voltages.—The office equipment must be protected as well as the power supply generator; this protection must be against high voltages which tend to break down insulation and against high currents which tend to burn out the wiring. Lightning arresters are installed to ground the high voltages induced by lightning discharges and fuses are used to protect against short circuits or crosses with power wires. Heat

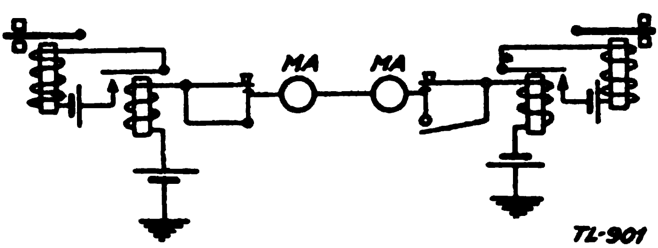


FIGURE 11.—Complete closed-circuit telegraph system.

coils are also employed. These devices are the same as, or similar to, those used in telephony and will not be described. Protective devices are installed wherever open lines join aerial, underground, or submarine cable and at all points where wires enter buildings.

8. Intermediate stations.—*a. Need.*—In practice, many telegraph circuits will be found to consist of more than two stations. It is customary, in such cases, to arrange the various stations involved along a continuous circuit. The circuit will therefore comprise a terminal station at each end of this circuit, with one or more intermediate stations connected into the line between them. These intermediate stations are usually referred to as "way stations."

b. Connections.—(1) *Closed circuit.*—Figure 12 shows the connections of a closed-circuit system consisting of two terminal and two intermediate stations, local-sounder circuits being omitted. Note that the intermediate stations are not grounded and have no line battery. In the event that the line breaks, stations on either

side of the break can ground their line on the side of their station toward the break and thus all stations on the same side of the break

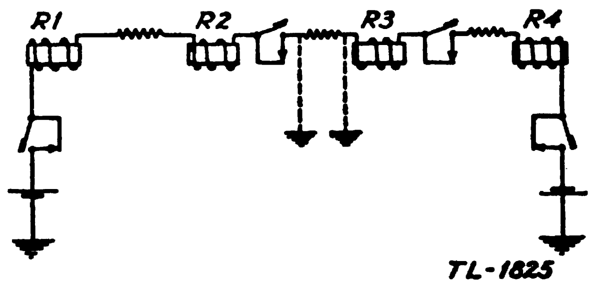


FIGURE 12.—Closed-circuit telegraph system with intermediate stations.

can continue to operate as a closed-circuit, single-battery system. For example, suppose the line to break between station *R2* and *R3*. Grounds would be established as shown in dotted lines, figure 12, resulting in stations *R1* and *R2* being able to operate with each other and, similarly, *R3* with *R4*.

(2) *Open circuit.*—Figure 13 shows the circuit of an open-circuit system consisting of two terminal and two intermediate stations. Note that each station in the system must have sufficient battery to operate the entire system, since when operating, the only battery on the line is that of the transmitting station. In the event of line breakage limited operation may be obtained as in the case of the closed-circuit system. Suppose the line breaks between *R2* and *R3*, then grounds established as shown in the dotted lines will enable the two halves of the system to function as two independent systems.

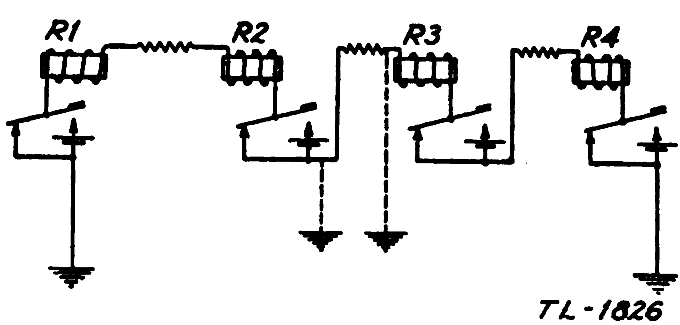


FIGURE 13.—Open-circuit system with intermediate stations.

9. Retardation and prolongation.—*a. General.*—The effect of the circuit constants upon transmission has not been considered. The wire of a telegraph circuit and the ground beneath it constitute a capacitor; at one end of this capacitor we have connected to it the battery, at the other end, the relay, which is an inductance of large

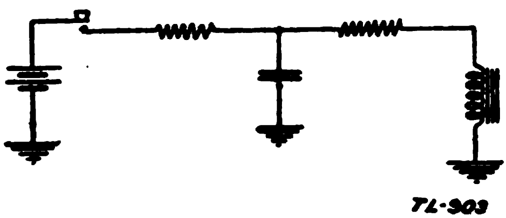


FIGURE 14.—Telegraph line constants.

value (since it consists of many turns of wire wound upon an iron core). In order to make a very crude explanation of what happens, let us make a rough representation of the telegraph circuit by the circuit shown in figure 14.

b. Retardation.—At the instant the key is closed, there is no charge upon the capacitor and therefore no voltage between its plates. There is therefore, no voltage applied to the relay at the distant end. As current flows into the capacitor, charging it, the difference of potential between its plates rises and this difference of potential is applied to the relay at the distant end. But not until the capacitor has been pretty well charged will the voltage applied to the relay be enough to drive through its resistance enough current to operate it. It takes an appreciable time to charge a capacitor; therefore the capacity of the line to ground has acted to slow-up the signal; that is, there is a delay between the time when the operator closes his key and the time when an appreciable voltage is applied to the distant relay. Nor is this all, for we have not yet considered that the relay has inductance. We know that current through an inductance does not rise at once to its final value but builds up along a logarithmic curve. Hence, even when an appreciable voltage is applied to the relay, there is another delay before the current in the relay builds up to a value sufficient to pull up the armature and thus close the sounder circuit. This time interval between the closing of the key and the click at the beginning of a dot or dash is called the "retardation."

c. Prolongation.—When the key is opened, inductance and capacity once more come into play. The inductance of the relay tends to keep the current flowing through it until it has discharged the energy stored in it; the capacitor cannot discharge through the open key so it will discharge through the relay, the direction of its discharge current being such as will tend to hold up the armature. This time interval during which the armature holds up after the key has been opened is called "the prolongation."

10. **Bias distortion.**—*a. Marking bias.*—If the prolongation is equal to the retardation, transmission is affected only in that there is a slight delay. If, however, the prolongation is greater than the retardation, the signal received at the distant relay will be longer than the sent signal. Since dots and dashes would be lengthened by the same amount of time, their relative lengths at the receiving station would be adversely affected. In the case of high speed transmission, this effect may be so great as to make signals unreadable. This distortion is known as marking bias, because it lengthens the signals while shortening the spaces between signals.

b. Spacing bias.—Spacing bias is a distortion which lengthens the spaces between signals and correspondingly shortens the signals. Adjustment of a relay may, within certain limits, be made to correct for bias introduced by circuit characteristics. Consider the curve shown in figure 15 in which current in the receiving relay is plotted against time. In order to send this signal, the key was closed at point *A* on the curve. The current, due to the delaying action of the capacitance and inductance of the circuit, builds up as in the *AE* portion of the curve. The *EF* portion represents the steady state; *F* indicates the opening of the key. The decay of the current is shown by the *FJ* portion of the curve. In this curve, the rate of build-up and decay are equal, the ideal condition. This type of curve will exist when the open circuit key is used and the key allowed to make its back contact when in the spacing condition.

c. Zero bias.—Suppose that the relay is adjusted so that a current equal to one-half of the normal line current is required for its operation. The relay will then operate at a point *C* on the curve and will remain operated until a point slightly beyond *H* is reached. The difference between the current value at the operate and release points on the curve is caused by the armature travel and the residual magnetism in the core and will vary widely with different relays and different adjustments of the same relay. This will

be neglected in this discussion. The key was held on marking for the time indicated by *K* in the figure. The relay was operated for the time *O* and as may be seen from the curve *O* and *K* are equal. Since the received signal was equal to the signal sent, the circuit may be said to have zero bias.

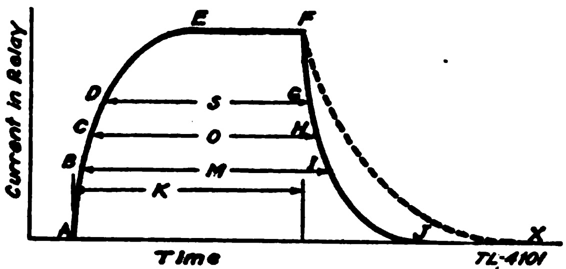


FIGURE 15.—Effect of relay biasing on signal length.

d. Bias adjustment.—If the spring on the relay has its tension increased to a point where the current required to operate the relay is as shown at point *D*, the received signal will be equal to *S*. Since *S* is smaller than *K*, the received signal is shorter than that sent, and system has spacing bias, likewise, if spring tension is decreased, the received signal will be as shown by *M*, and the system has marking bias. It may be seen that the spring tension can be used to control the bias of the received signals. The spring is sometimes referred to as biasing the relay. The spring could be replaced by another winding on the relay. Current can be placed through this winding in such a direction as to oppose the pull provided by the main winding. In this case, the extra winding is called a biasing winding and the current in this winding is called the biasing current.

e. Decay with sending key open.—In the above discussion, it was assumed that the sending key, while in the space condition, grounded the line. This does not normally exist in the closed circuit system; thus, the capacitance of the line must discharge through the receiving relay only, and the time required for the decay of the current is greater than that for the build-up. The decay will be as indicated by the dotted line *FX*. It may be seen from the figure that marking bias would result if the spring tension or the bias current were not kept at a value somewhat higher than one-half the normal line current.

11. Comparison of open- and closed-circuit systems.—*a. General.*—Before dismissing the subject of single-line telegraphy, it would be well to state the relative merits of the closed- and open-circuit systems. With one or two exceptions, these have been developed above and only a resume is needed here.

b. Advantages of closed-circuit system.—(1) *Fewer batteries.*—The closed-circuit system requires fewer batteries. Its one battery may be divided between the two ends, but the total voltage used remains the same as though it were concentrated. In the open-circuit system there must be at each station, including intermediate stations, sufficient battery to operate the entire line. In railroad dispatching where a dozen intermediate stations may be employed, the number of batteries would be prohibitive if the open-circuit system were employed.

(2) *Trouble indication.*—The closed-circuit system gives a definite indication when the circuit is opened by trouble. When the line is normal and the circuit idle, the sounder bar remains operated, thus when the line is opened the bar is returned by the spring, giving a click.

c. Advantages of open-circuit system.—(1) *Economy of power supply.*—In the closed-circuit system current flows in main-line and local circuits when no messages are being sent; in the open-circuit system current flows only while dots and dashes are being transmitted. Where the system is used steadily, this apparent disadvantage of the closed system is not great. It is also to be remembered that gravity cells operate better with fairly continuous use. The power used in a telegraph circuit costs very little in comparison with the other items of telegraph costs, and the saving of power by the open-circuit system may be wholly neutralized by the increased capital cost of so many batteries. Where the source of power is dry cells as in military field circuits, the question of dry cell replacement in the field may be a serious problem. Military lines are apt to stand idle much of the time, and, during these times, energy is being drawn from the dry cells if the closed-circuit system is used.

(2) *Leaky lines.*—The open-circuit system works better over leaky lines. This was shown in the discussion accompanying figures 9 and 10. With the hookup of figure 9, East's working margin was the same as that of any station in an open-circuit system with the same resistance and battery voltages. In wet weather, this was 30 milliamperes. Under wet weather conditions the closed-circuit

system of figure 10 had a working margin at either end of only 22.5 milliamperes. Better working margin is obtained for the open-circuit system because no leakage current flows in the receiving relay. Thus, all stations in the open-circuit system have the same working margin as has the station away from the battery in single battery closed-circuit operation.

(3) *Signal distortion.*—The open-circuit system is less subject to bias distortion than the closed-circuit system as discussed in paragraph 10*e*.

12. Questions for self-examination.—

1. What are three advantages of telegraphy?

2. What are three advantages of telegraphy over radio?

3. For what use in army field communication systems is the telegraph ideally suited?

4. Give two reasons for not putting the sounder in the main line.

5. What is meant by a ground return?

6. What are the chief advantages of the ground return?

7. What is the difference between open- and closed-circuit keys?

8. Give four disadvantages of the ground return.

9. What factors limit the distance over which telegraphy may be operated?

10. Where does leakage occur in a telegraph circuit?

11. Under what conditions is line leakage greatest?

12. Explain what is meant by "working margin."

13. An operator working over a very leaky line should observe what precaution?

14. Draw a diagram of a complete closed-circuit telegraph system consisting of three stations.

15. Draw a diagram of a complete open-circuit telegraph system of three stations.

16. What sources of power are used in central offices?

17. What source of power would be used for a field telegraph station in the army?

18. What is a protective resistance and why is it used?

19. How is the size of the protective resistance determined?

20. What properties other than resistance has a telegraph line?

21. What is the effect of line to ground capacity upon telegraph transmission?

22. What is the effect of inductance of the relay on telegraph transmission?

23. Over long leaky lines, which works better, open- or closed-circuit telegraphy?

24. What are the relative merits of open- and closed-circuit telegraphy?

25. What is meant by bias distortion?

26. What is meant by relay bias?

SECTION II

SIMPLEXED, COMPOSITED AND PHANTOMED CIRCUITS

13. General.—Wires may be used simultaneously for telephony and for telegraphy without interference between the two means of communication. When two wires are utilized to give one telephone and one telegraph channel, the practice is called simplexing. If the two wires provide one telephone channel and two telegraph channels, the circuit is said to be composited. Both methods will be briefly explained and their suitability for army use discussed.

14. Repeating-coil simplex.—*a. Methods.*—Two methods of simplexing exist: the repeating-coil and the bridged-impedance meth-

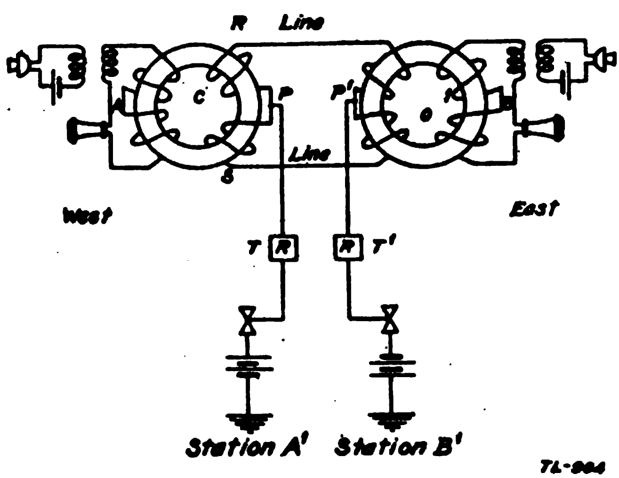


FIGURE 16.—Telephone circuit simplexed for telegraph by use of repeating coils.

ods. The repeating-coil method is used almost universally and is the one to be discussed in this text. It is illustrated in figure 16.

b. Telephone interference in telegraph.—Examination of the figure will show that if the resistances of the two wires be equal, P and P' are always at the same potential as far as the telephone currents are concerned. The two windings of the secondary of the repeating coil are identical and are connected in series; therefore when West is talking, the potential of P is halfway between that of R and that of S. The resistance from R to P' is the same as that from P' to S; hence the potential of P' is halfway between that of R and that of S. Hence P and P' may both be connected to ground and electromotive forces induced in the secondary of the repeating coil by talking into the transmitter, will not cause any current to flow from P to ground and thence to P'. So P and P' are connected together through the telegraph apparatus and ground and no telephone current flows through this telegraph circuit.

c. Telegraph interference in telephone.—Consider why the telegraph currents do not affect the telephone. Current coming from the battery at A' divides equally at P, flowing thence towards R and S. But the flux produced by the winding PR is equal and opposite to the flux produced by the winding PS; therefore no electromotive force is induced in the two windings connected to the receiver of the telephone.

d. Circuit balance.—In the explanation above, it was shown that the telegraph and telephone would not interfere with one another if the two line wires had the same resistance. If the current in a telegraph line were only steady direct current, the requirement of equal resistance in the two line wires would be all that is necessary. But since each dot or dash closes the circuit at its beginning and opens it at its end, transient currents will flow in the line. For example, closing the key causes the current to rise from zero to its final steady value; during the time the current is changing, the capacity of the line plays an important part. Hence if the simplexed circuit is to be balanced, it must be balanced not only for resistance but also for capacity. In practice, the lines used by the army in its field systems will not be balanced and a key thump will be heard in the telephone; this thump is not objectionable unless it is very strong. The telephone user, intent upon his conversation does not notice the thump any more than one notices ordinary noise during a normal conversation.

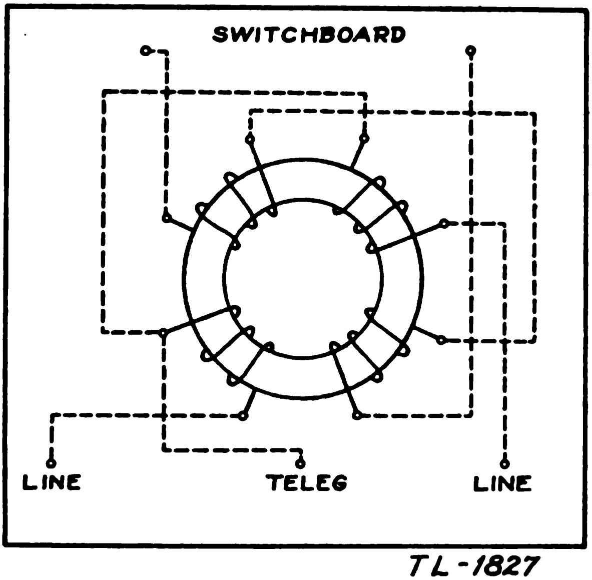


FIGURE 17.—Repeating coil C-75 or C-161 showing internal connections.

e. Connections.—The connection to the terminals of a typical repeating coil used by the army are shown in figure 17. Dotted lines represent connections which are made between the windings and the terminals; these are integral with the coil. To install the coil for a simplex, connect the switchboard or telephone to the terminals marked "Switchboard," connect the line to terminals marked "Line" and the telegraph set to the terminal marked "Teleg."

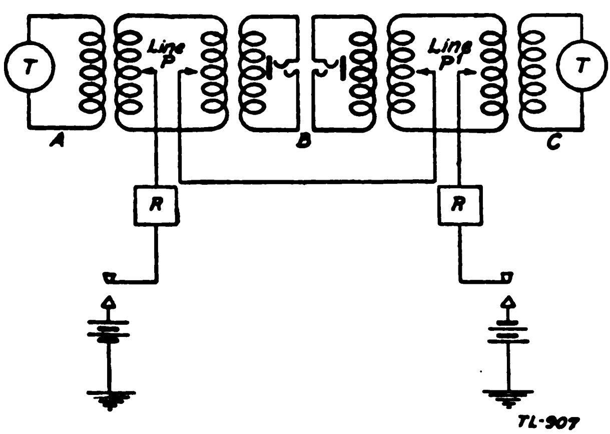


FIGURE 18.—Simplex circuit bridged around an intermediate switchboard.

Simplexing may be resorted to in getting a telegraph circuit between points *A* and *C*, where telephone circuits connect both *A* and *C* to a switchboard at *B*. The circuit is shown in figure 18. Note that two repeating coils are required at *B* and that an intermediate telegraph station could be set up at *B* by connecting the telegraph apparatus between *P* and *P′*. The repeating coils are shown schematically, without respect to the direction of the windings. This method of representation is the accepted one, where it is not desired to check the actual direction of current in the windings.

15. Compositing.—As stated at the beginning of the section the two line wires may be made to yield one telephone channel and two telegraph channels; this is called compositing. The circuit used is illustrated in figure 19. The telegraph current cannot flow into the telephones because of the capacitors and the telephone currents are little affected by the telegraph circuit because of the very high inductance placed between the line wire and ground. To improve operation, additional apparatus is connected in, but this is not essential to an understanding of the method and is therefore omitted from the figure. An intermediate station is shown in one of the telegraph circuits to illustrate the manner of connecting it.

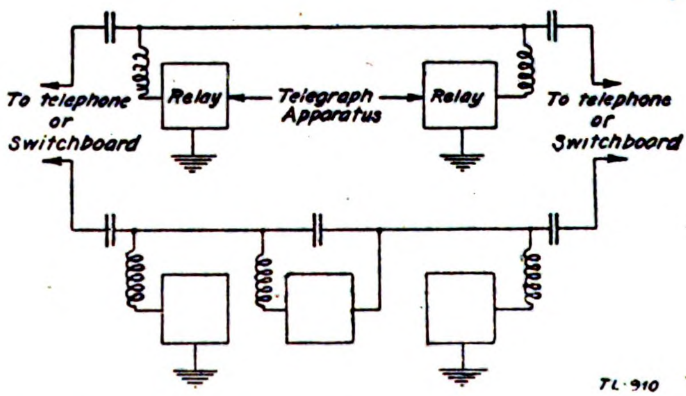


FIGURE 19.—Telephone circuit composited for telegraph. A balancing impedance, not shown, may be used in the upper line wire.

16. Comparison of the two methods.—At first glance compositing seems a more desirable method than the simplex, since it gives an additional telegraph channel. However, it has drawbacks from the viewpoint of military use. The retardation coils have high imped-

ance for voice frequency currents but the 20-cycle ringing current passes readily through them and causes the telegraph relays to chatter. Commercially, this difficulty is overcome by the use of ringing currents of higher frequency. Also the apparatus required for compositing is more complex and requires more expert installation. Finally, military practice requires so many telephone channels as minimum requirements, that if all of these be simplexed, a sufficient number of telegraph channels will have been obtained.

17. **Phantom circuits.**—If a metallic return for telegraph is required to eliminate difficulties encountered in a ground-return system, two simplex circuits may be used. The combination is called a phantom circuit. The phantom circuit may be used for telephone as well as for a metallic telegraph circuit. A phantom circuit is shown in figure 20. No mutual interference is noted in the system if wires *A*, *B*, *C*, *D*, and their associated equipment are balanced, that is have equal resistance, inductance, capacitance to ground and are properly transposed. Transpositions are discussed later in the text.

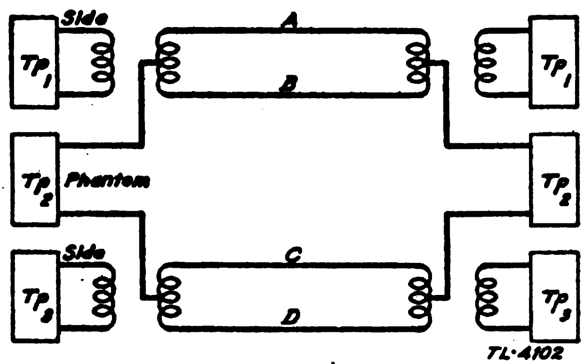


FIGURE 20.—Phantom group.

18. **Combination of simplex, phantom and composite groups.**—*a. Simplexed phantom group.*—Phantom circuits may in turn be simplexed for telegraph and thus three telephone and one telegraph circuit may be obtained in two pairs of wires called a phantom group. A simplexed phantom group is illustrated in figure 21. Theoretically an additional circuit could be derived from this group and another similar group but the problems involved in transposing and maintaining a balance on a system consisting of more than four wires usually make it impracticable.

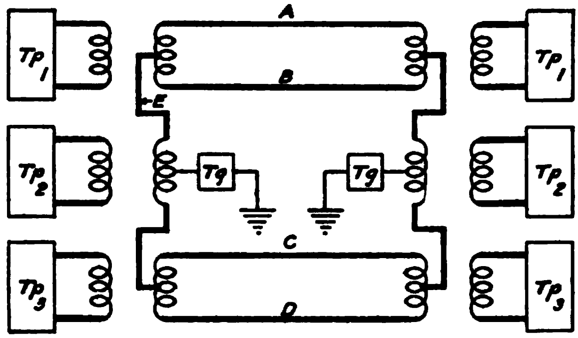


FIGURE 21.—Phantom group with phantom simplexed for telegraph.

b. Compositing of phantom.—The side circuits may be phantomed in the usual manner and the phantom composited thus providing three telephone and two telegraph channels on the four wires. Composite ringing is required for the phantom telephone circuit but normal 20-cycle ringing may be used on the side circuits.

c. Both side circuits composited.—The two side circuits may be composited and a phantom placed on the group, but composite ringing must be used on all three telephone channels. This system will provide three telephone and four telegraph channels on the four wires, the maximum number of circuits available on a group without the use of carrier. Carrier circuits will be discussed later in the text. It might at first seem that the phantom in this system could itself be simplexed or composited but it must be remembered that direct current telegraph systems cannot work through a capacitor, therefore a composited circuit cannot be re-composited.

19. Mutual interference in simplex and phantom groups.—*a.* When the wires composing a simplex or phantom group have unequal impedances, interference will result; the greater the unbalance, the greater will be the interference. Possible causes of unbalance are excessive series resistance due to poor splices, unequal leakages to ground, improper transpositions or in the case of a phantom group a cross between two wires of different pairs. It should be noted however that a short between two wires of the same pair will of course put the telephone on that pair out of service but the service on the other side circuit, the phantom and the simplex will not be adversely affected.

b. The interference resulting from any unbalance is usually more pronounced in a phantom group than in a simplex group as there are more circuits involved. Also, mutual interference between two telephone channels is more serious, due to the similarity of sound, than is the interference between telegraph and telephone.

20. Questions for self-examination.—

1. Is the repeating coil, used for simplexing, a ring-through, or nonring-through coil? Why?

2. Why should telegraph communication always supplement telephone communication in army field systems?

3. Make a diagram showing how the terminals of a repeating coil are connected when simplexing a telegraph circuit upon a telephone circuit?

4. For perfect simultaneous operation of a telegraph channel and a telephone channel over two wires, what must be true of the two wires?

5. There are two telephone lines from First Army switchboard to I Army Corps switchboard and two telephone lines from I Army Corps switchboard to 1st Division switchboard. Show by a diagram how these lines could be utilized to obtain three telephone circuits from First Army to I Army Corps, three telephone circuits from I Army Corps to 1st Division and one telegraph circuit from First Army to 1st Division, the latter channel including an intermediate telegraph station at I Army Corps.

6. How many telegraph channels may be obtained from a metallic telephone circuit by compositing?

7. Show by a diagram the principle of compositing.

8. Why is compositing usually not suitable for use by the army in the field?

9. Referring to figure 21, what is the effect of the following troubles on operation of each of the three telephone channels and the telegraph channel?

a. Short between wires *A* and *B*.
b. Open in wire *A*.
c. Ground on wire *C*.
d. Cross between wires *A* and *D*.
e. Open in wires *C* and *D*.
f. All four wires shorted together.
g. Open in wire *E*.

SECTION III

GROUNDS

21. General.—*a. Purpose.*—Professor Steinheil in 1837 made the discovery that the earth may be used as a portion of an electric circuit. It is used as such to a considerable extent in telegraphy. Its use in telephone communication introduces noise in the circuits caused by induction from neighboring power lines and causes cross-talk between adjacent circuits. It is therefore little used in telephone communication except to drain off lightning and other static disturbances.

b. Connections.—Connections to the earth are usually called grounds and may be obtained by connection to buried pipe systems, buried plates, buried wire or driven pipes or rods. Where pipe systems are not available, driven rods are the usual method because of the ease of installation.

c. Resistance of ground return path.—It might seem at first thought that the resistance of the ground return path would be fairly high. It is true that the specific resistance of the earth is very high in comparision with that of a metallic conductor, but the cross sectional area of the path is very large, therefore the resistance between any two ground rods is relatively low if a good connection is obtained. Since the cross sectional area of the path is smallest near the electrode, the greatest share of the ground resistance is here; therefore, good conductivity of the soil near the electrode is essential.

d. Factors affecting resistance of connection.—The resistance of a ground connection may vary from a fraction of an ohm to several thousand ohms depending on a number of factors. Some of these factors are: the nature of the soil, moisture content of the soil, the physical dimensions of the connection, the material of the connection and the effect of the past corrosion and electrolytic action.

22. Variation of resistance of a ground rod.—*a. Depth.*—The resistance of a ground rod decreases with increase in depth quite rapidly for the first few feet but, except in the case of unusually high resistivity of the soil in the upper layers, little advantage is gained by the use of rods longer than five feet. It is often found, however, that moisture content of the soil is higher at the lower levels. In freezing weather, ground rods should be long enough to reach below the frost line.

b. Rod diameter.—When the ratio of the length of a ground rod to its diameter is large, as it usually is, only slight advantage is gained by increasing the diameter of the rod. Diameter of the rod should therefore only be large enough to permit easy installation.

c. Electrode material.—Experimental work has shown that the metal used for electrodes is unimportant except as to its resistance to corrosion. Copper clad rods are probably the least subject to corrosion of any of the types in common use. Iron rods, plain and galvanized, are quite extensively used and give good service. The iron oxide which forms on plain iron rods is not detrimental as its conductivity is better than the surrounding soil.

d. Soil conditions.—The features of soil which make it advantageous for grounding are the presence of moisture and the concentration of salts dissolved in this moisture. Grounds obtained by rods of the same length in different types of soils may vary from a few to several thousand ohms. The following list arranges soils of various types in order of ascending specific resistance: wet soil, clay or loam, clay or loam with sand and gravel, wet sand, dry sand, gravel and stones.

e. Chemical treatment.—Where high ground resistances are encountered due to lack of salts in the soil, these resistances may be reduced by placing salt in an excavation around the top of the rod, then wetting thoroughly. Salts most commonly used are sodium chloride, calcium chloride, sodium nitrate and copper sulphate.

23. Multiple rods.—It has been found from various tests that 90 percent of the total potential drop around a ground rod generally occurs within 6 to 10 feet of the rod, depending on the length of the rod and the nature of the soil. It may be considered then that the effective electrode consists of a volume of the earth surrounding the rod. When paralleling two or more rods together, it is desirable to space them so that the effective electrodes do not overlap to any considerable extent. Five-foot rods should in general be spaced not closer than 8 feet and preferably 15 feet apart. Longer rods should have spacing at least as great as their length. Even with this spacing, the actual resistance of parallel combination will be higher than that computed from their separate resistances. In general, the greatest benefit is obtained from paralleling grounds when the specific resistance of the soil is high.

24. Earth potentials.—It will usually be found that between any two ground rods placed some distance apart that a potential exists. This potential will in most cases be fluctuating. It arises from various natural and artificial currents flowing in the earth due to power systems, street railway systems, Aurora Borealis, lightning etc. Potentials will, at times, be large enough to interfere seriously with telegraph communication and may be, in some cases, high enough to be dangerous to life, particularly in the case of long commercial lines.

25. Measurement of ground resistance.—Accurate means of determination of ground resistances are difficult and in many cases meaningless because of the wide changes which may take place after the determination has been made. Determinations under conditions which simulate actual use are desirable when practicable. A useful field means of determining whether a ground is suitable for use on a teletypewriter circuit is to set up a teletypewriter for local operation between two ground rods spaced about thirty feet apart. Have the line rheostat adjusted to a value at least as great as the resistance of the line on which the teletypewriter will be placed. If satisfactory local operation is obtained, connect the two rods together and use the combination for the ground connection for normal use.

26. Ground connections for field wire systems.—In the usual case in which a ground return circuit is used, a low-resistance ground connection is necessary for each terminal station not only to insure

sufficient operating current, but also to prevent interference with neighboring telegraph circuits. It is almost always possible to obtain a good ground by proceeding as follows:

a. Drive a ground rod into the ground where it is moist. Usually, except in very dry weather, the ground near the roots of a shrub or tree is moist. If only dry ground is available, wet it thoroughly and pack it down around the rod.

b. Use a separate ground for each telegraph set or other equipment and keep separate grounds at least 15 feet apart.

c. Use two or more ground rods at least 15 feet apart connected together if one ground rod will not suffice.

d. Keep the wire leading from the ground rod to the set as short as possible, but do not hesitate to use a wire several hundred yards long if necessary to reach moist ground, such as a stream bed.

27. Line battery.—In field telegraph systems, high resistance grounds may be partially compensated for by use of additional line battery when means to lower the resistance have failed. Direct earth potentials may, in some cases, cause faulty telegraph operation. If this is suspected, reverse the line batteries so that the earth potential aids rather than opposes the voltage of the batteries.

28. Questions for self-examination.—

1. What is the importance of having low resistance ground connections in communication systems?

2. How does the resistance of a ground connection vary with each of the following factors? Why?

(a) Moisture content of the soil.
(b) Salts in the soil.
(c) Material in the ground rod.
(d) Length of the ground rod.
(e) Diameter of the ground rod.

3. Describe a method of determining if the resistance of a ground is low enough for satisfactory operation.

4. What is the purpose of using multiple ground rods? What spacing should be used for multiple rods?

SECTION IV

TELEGRAPH RELAYS

29. Simple neutral relay.—The relay described in paragraph 3 which has been used in the circuits considered so far in this text may be said to be a simple neutral relay. It is called simple because it has only one winding with two terminals. It is called neutral because it will be operated by a current flowing in either direction through this winding.

30. Differential neutral relay.—A differential relay is one which has two windings, so connected that the flux from one winding opposes that produced by the other and thus the relay is operated by the difference between the current in the two windings. Such a relay is illustrated schematically in figure 22. In this figure the

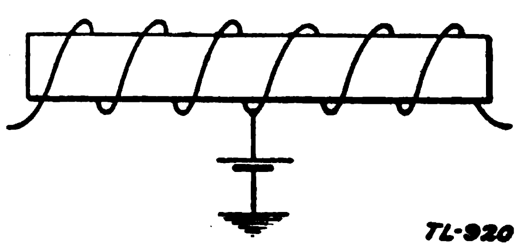


FIGURE 22.—Differentially-connected relay winding.

two windings have a common terminal which is shown connected to the battery. In practice all terminals are usually brought out separately in order to provide flexibility in the method of con-

nection. If the two windings are connected in series with the battery, their fluxes are in the same direction and the relay may be used as a simple relay; if the two windings are connected in series and the battery applied to the common connection as shown in the figure, the relay is a differential one, since the fluxes now oppose. The windings may be used in parallel if desired.

31. Differential polar relay.—*a. Definition.*—A polar relay is one which will move its armature in one direction when current is passed through its winding in one direction and which reverses the direction of movement when the current is reversed. Such a relay when adjusted for zero bias will, with no current in its winding, remain in either position when operated manually, or remain in the mid-position, depending on the type of relay.

b. Operation.—The principle of the polar relay may be understood with the aid of figure 23. A U-shaped permanent magnet, magnetized so as to have two equal south poles as indicated in (a), has pivoted at its midpoint a soft-iron armature, which projects upward and plays between two pole pieces attached to the ends of the magnet, as shown in (b). The upper end of the armature is then a north magnetic pole and it is evident that the armature will remain against whichever pole piece it is placed, since no spring is used. A winding surrounds each pole piece and the two windings are connected in series. If the current is in the direction shown in (c), the field due to the current will weaken the magnetism of the left-hand pole piece and strengthen that of the right-hand one. Consequently, the armature, a north pole, will be drawn towards the stronger south pole. If the current were reversed, the armature would be pulled back towards the left.

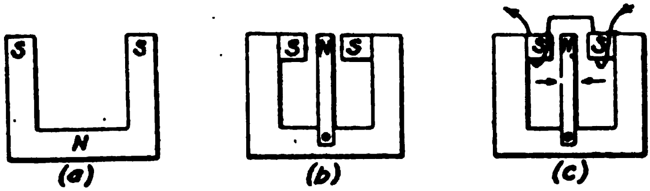


FIGURE 23.—Construction of a polar relay with permanent magnet core.

c. Connections.—Polar relays may also be wound differentially. Each winding has the same number of turns about each pole piece. A differentially wound polar relay is represented schematically

in figure 24. If equal currents flow from *P* through the windings, the pole strengths will be unaffected and the armature will remain wherever it was before the currents commenced to flow. However, if current enters at *R* and leaves at *P* and *S*, the two south poles will be unequal in strength; the armature will be drawn to the left.

32. Polar relay without permanent magnet.—A relay with the same general characteristics as that described in paragraph 31 can be made by adding a biasing winding to a neutral relay. The current in this biasing winding is adjusted so that the magnetic attraction for the armature balances the pull exerted by the spring. When the current in the main windings is in the direction to aid the flux produced by the biasing windings the armature is pulled to the mark contact but when the flux produced by the main winding opposes that of the biasing winding the armature moves to space. It should be noted, however, that if the flux produced by the main winding opposes and is equal to that in the biasing winding, the total flux is zero and an increase of current in the main winding will pull the relay to mark even though the current is in the spacing direction. This action takes place when the flux produced by the main winding is slightly greater than twice that of the biasing winding. Difficulty of this sort can be avoided by keeping the biasing current and the corresponding spring tension high, thus preventing the total flux from passing through zero.

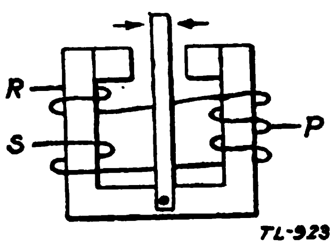


FIGURE 24.—Differentially-wound polar relay.

33. 215-Type Western Electric relay.—*a. Description.*—A type of polar relay in common use commercially is the Western Electric type 215. The essential features of this relay are shown in figure 25. The magnet is a permanent magnet made of hard steel. The two yokes, the reed and the pole pieces are made of permalloy which is a special alloy that conducts magnetic lines of force in the same manner that soft iron does. The reed is a thin strip

clamped at its base. It is the relay armature. It can be flexed from the marking to the spacing contact but due to the fact that it is a spring it stands midway between the pole pieces when no current flows in the winding.

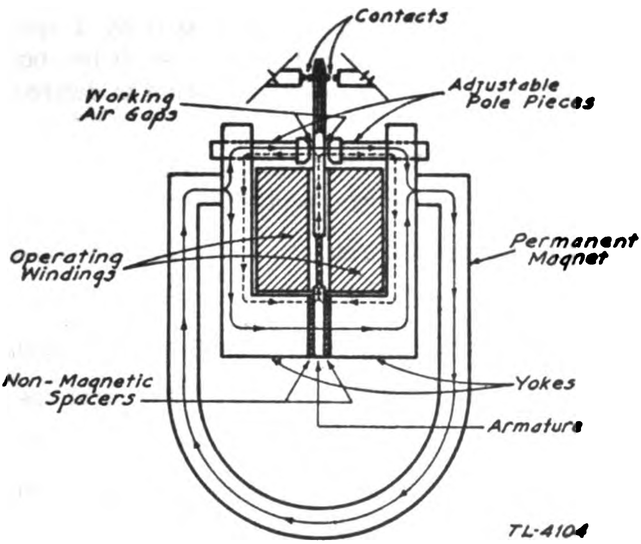


FIGURE 25.—Western Electric Co. 215-type relay.

b. Flux.—Due to the permanent magnet, lines of force flow as shown by the dotted arrows. No flux flows in the reed because the upper and lower ends are at the same magnetic potential. If a current of one polarity flows in the windings it will cause flux as shown by the dotted arrows. No flux flows in the reed because the the right pole piece and opposes that in the left. The reed thus moves to the right. A current in the opposite direction in the winding will move the reed to the left. One contact may be designated mark and the other space, the marking and spacing contacts being closed on the two direction of currents in the windings. The 215–A relay has two equal windings; others of the same general construction may have different winding arrangements.

c. Use.—The sensitivity and speed of operation of this relay make it suitable for use on teletypewriter circuits and it has a wide application in commercial printers and repeaters. It is designed for use on polar systems but can be used in neutral systems if a biasing current is supplied.

34. 41-Type Western Union relay.—The Western Union 41-type relay is used in the line unit *BE–77* which is turn a part of the teletypewriter *EE–97*. This relay is of the neutral type but has two equal windings and may be used for polar operation as shown in paragraph 32. The resistance of each winding is about 100 ohms. The relay is of the plug-in type and is biased by a spring under control of a thumb screw at the end of the case. It has both a front and back contact for use when polar operation is desired.

35. Questions for self-examination.—

1. What is meant by a neutral relay?
2. What is a differential relay?
3. What is a polar relay?
4. How may a neutral relay be arranged for polar operation?
5. How may a polar relay be arranged for neutral operation?
6. What kind of relay contains a permanent magnet?
7. How many windings are necessary on a neutral relay if it is to be used as a polar differential relay?

SECTION V

DUPLEX TELEGRAPHY

36. Meaning of duplex.—That method of telegraphy by which messages are simultaneously sent and received over one circuit, is called duplex telegraphy. A sending operator and a receiving opertor are required at each end. Several methods of duplex telegraphy exist; the single-current differential, the double-current differential, the single-current bridge, the double-current bridge, and the Morris short-line duplexes. For reasons to be pointed out later, the double-current systems are preferred in actual use, but to make their understanding easier, the single-current differential duplex will be described first.

37. Single-current differential duplex.—*a. General.*—In order to receive a message at the same time that one is being sent from the station, the relay must not respond to the key of the home sending operator but must respond to the key of the sending operator at the distant station. To accomplish this, the relay used must be of the differential type. The key used is an open-circuit telegraph key, the back contact being connected to ground through a resistance. The type of relay used in single-current differential duplex telegraphy is illustrated schematically in figure 22. The same differential effect is given by the relay of figure 26 since the current, flowing from the battery, divides at the midpoint of the winding and current flows around the core in opposite directions from that point.

b. Operation.—(1) The circuit in which this relay is used is shown in figure 26. The line resistance has been assumed to be 1550 ohms; the resistance of each winding of the relay has been assumed to be 400 ohms, the normal practice; the sum of the protective

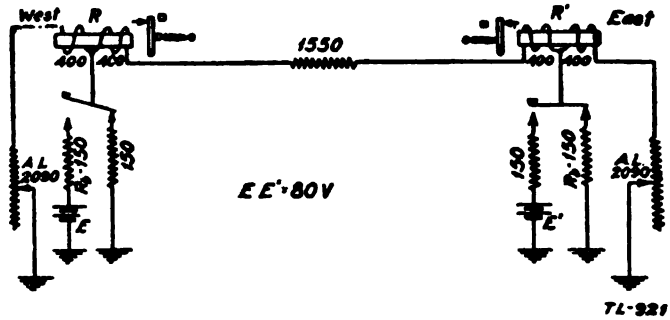


FIGURE 26.—Single-current differential duplex system.

resistance and the internal resistance of the battery is assumed to be 150 ohms; the foregoing resistances determine the other resistances which must be used, as will be seen from the explanation below. *AL* stands for "artificial line"; it is merely a resistance, whose value is determined by the resistances assumed above. The resistance between the back contact of the key and ground must be the same as the resistance between the front contact and ground. In the figure, neither operator is sending and, therefore, both keys are on the back contacts. No current flows in the line or through the relays; neither armature is pulled up.

(2) Now suppose East and West start sending simultaneously, East to send a dot and West to send a dash. Both keys are on the front contacts. In the circuit from ground, through West's battery, the right hand winding of West's relay, the line, the left hand winding of East's relay, through East's battery back to ground, we have two equal batteries connected opposing one another. Therefore no current flows in the circuit just traced. There is a path from ground, through West's battery, the left hand winding of West's relay, and the artificial line back to ground. A current of 30 milliamperes flows in this circuit, energizing the relay and pulling up the armature of West's relay. A similar path exists at East and East's relay armature is also pulled up.

(3) Since East is sending a dot, he releases his key before West does his. Consider whether the armatures operate properly. East has released his key which now rests on the back contact; hence East's battery is out of the circuit. It is now necessary to determine what current flows because of West's battery. Starting from ground, current flows through West's battery up to the midpoint of West's

relay, where it divides. If it divides equally at this point, the flux produced by one winding will be equal and opposite to the flux produced by the other and the relay will not be energized. The armature will fall back (which it should do, since East has just finished sending a dot). The current will divide equally at the midpoint if the resistances to the left and right of the midpoint are equal. The resistance on the right is:

$$400+1550+400+\frac{150\times(400+2090)}{150+400+2090}=2490 \text{ ohms (approx.)}.$$

The resistance on the left of the midpoint is also 2490 ohms. Therefore, the current does divide equally and West's relay is not energized. The current which flows through East's relay is all in the the same direction; the fluxes produced add together, and East's relay is energized. It should be, because West is still sending his dash. It is seen from the above that the relay at each station is properly actuated, regardless of the position of the key at that station.

(4) Note that the artificial line must be of such resistance as will cause the current to divide equally at the midpoint of the home relay when the distant key is on the back contact. The necessary value of the artificial line resistance may be computed, knowing all the other resistances in the circuit. However, it is much simpler and easier to adjust the artificial line until the home relay is not actuated when the home key is depressed. The operation of all duplex systems is improved by making the artificial line conform more closely to the characteristics of the actual line by adding capacity to the former. The needed capacity is not computed but is arrived at by adjustment.

38. Double-current differential duplex.—*a. Reasons for use of double current.*—Certain inherent disadvantages of single-current telegraphy lead to the use of double-current telegraphy. The principal disadvantages are: spacing is accomplished by interrupting the current or by neutralizing its magnetic effects; due to residual magnetism of the relay core, the action of the armature will be uncertain when the current interrupted is weak; induction from neighboring circuits may cause the armature to pull up during a space. In double-current telegraphy, the back contact of the key is connected to ground through a battery which is poled opposite to that connected to the front contact. This requires the use of two batteries

or generators at each station or the use of a single battery with a pole changer. Since current always flows in the double-current system, the method is more positive in its action. The beneficial effect of a split battery upon leakage is also gained. The slowing up of operation, due to the capacity, is overcome because the charge, instead of having to leak off when the key changes contacts, is neutralized by current from the oppositely poled battery.

b. Operation.—(1) *Both spacing.*—The circuit of the double-current differential duplex is shown in figure 27. Assume the resistances to be as shown; they are the same as those of figure 26 and are arrived at in the same way as in that case. If no operator is sending both keys are on the back contacts. Because of

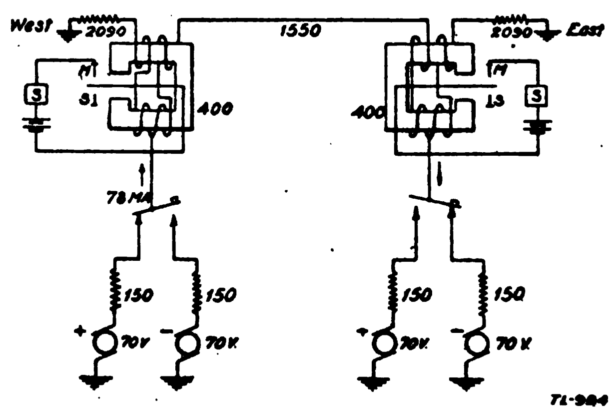


FIGURE 27.—Double-current differential duplex system.

the equal batteries opposing one another no current flows in the line. Current flows from each battery through the outer relay winding and artificial line to ground. The direction of the flux is such as to make the lower pole a stronger south pole than the upper and the armature is drawn against the space contact (marked *S* in the figure). This is an idle contact, connected to nothing, whereas the mark contact, *M*, closes the sounder circuit when in contact with the armature.

(2) *Both marking.*—Assume that East and West start sending simultaneously, East sending a dot and West sending a dash. It is customary to connect the two generators as shown in figure 27 so that when spacing, positive battery is connected to the line by the key touching the back contact, and negative battery is put on the

line when marking. Both operators, by depressing their keys, connect negative battery to the line. Since the two batteries oppose and are of equal voltage, no current flows in the line or the right-hand winding of West's relay or the left-hand winding of East's relay. About 27 milliamperes flows through the left-hand winding of West's relay; the direction of this current is such as to make the pole marked *M* stronger and that marked *S* weaker. Hence, the armature, being a north pole, is pulled towards *M*, closing the sounder circuit and beginning the dot which East is sending. A similar current, flowing through the right-hand winding of East's relay, causes the armature to move against the contact *M*, closing the sounder circuit and beginning the dash which West is sending.

(3) *One marking, one spacing.*—A fraction of a second later, East completes the dot and lets up on his key, thus connecting positive battery to the line at his end. West's key is still down, connecting negative battery to the line at his end. Finding the values of the currents in the different parts of the circuit is a problem which must be solved by the use of Kirchoff's laws; the solution is tedious and will not be entered into. A current of 74 milliamperes flows from East's battery to the midpoint of his relay, where it divides, 50 milliamperes going to the line and 24 milliamperes going to the artificial line. The 50 milliamperes in the line is joined at the midpoint of West's relay by a current of 24 milliamperes flowing from ground through West's artificial line: 74 milliamperes flows from the midpoint through West's battery to ground. In East's relay, the current flowing in the left-hand winding is greater than that in the right-hand winding and, therefore, controls the polarity; the pole marked *M* is more strongly south. This pole holds the armature up aginst the contact *M*, keeping the sounder circuit closed. This is what it should do, since West is still sending a dash. In West's relay, the current in the right-hand winding is the greater and its direction is such as to make the pole marked *S* more strongly south. Therefore, the armature of West's relay moves over against the contact *S*, breaking the sounder circuit and thus completing the dot which East had just finished sending.

(4) *Keys in intermediate position.*—In the manipulation of the keys in both single- and double-current differential duplexes, there are constantly recurring intervals during which the key is in an intermediate position, touching neither front nor back contact. This condition is apt to cause confusion of signals, especially on leaky

lines. The difficulty is overcome by the use of a continuity preserving transmitter. This simple instrument will not be explained in this text.

39. **Bridge duplex.**—*a. Principle.*—The principle of the Wheatstone bridge is applied in another method of duplex telegraphy, called the bridge duplex. As seen from either end, the circuit is a balanced bridge in which the nearer relay is connected where the galvanometer would normally be. The relay used is a polar relay. (The relay may be the same type used for double-current differential duplex but the windings are connected in series instead of differentially.) To facilitate understanding of the operation of the double-current bridge duplex, a simplified diagram of a typical circuit is shown in figure 28. *P* and *P′* are the relays, represented in the figure as simple resistances.

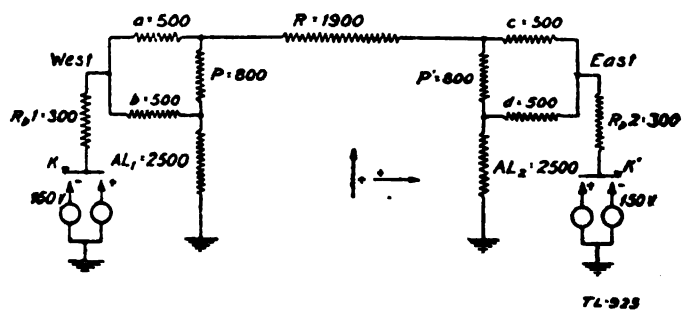


FIGURE 28.—Simplified diagram of bridge duplex system.

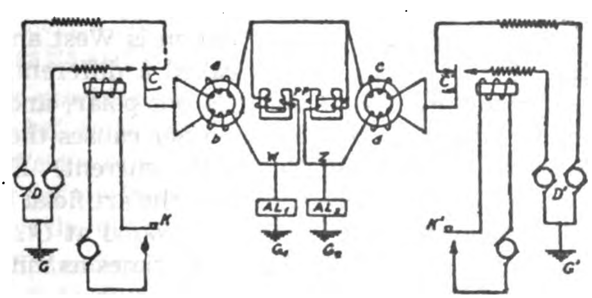
b. Operation.—(1) *Both spacing.*—With neither East nor West sending, the keys rest on the back contacts, connecting positive battery to the line at each end. No current flows in *R,* since equal batteries are connected opposing each other. Current flows from West's battery through R_b1: this current divides, part flowing through *b* to AL_1, the remainder flowing through *a* and *P* to AL_1. This current through *P* is directed down and the relay, which is *P*, is so connected that current down causes the armature to pull over against the space contact. Similarly, it will be seen that current flows down through *P′*, East's relay, causing its armature to rest against the space contact.

(2) *Both marking.*—Now suppose East and West start sending simultaneously, East sending a dot and West sending a dash. Both keys are on the front contacts, thus connecting negative battery to

the circuit at either end. Again no current flows in R. But current flows from ground through AL_1, dividing, part going through b to R_o1, and part flowing through P and a to R_o1. The current through P is now up and if current directed downwards through the relay P caused the armature to rest against the space contact, this upward current will pull the armature over against the mark contact, closing the sounder circuit and beginning the dot which East is sending. Similar analysis will show that the current through East's relay, P', is also directed upward, closing his sounder circuit and beginning the dash which West is sending.

(3) *One marking, one spacing.*—When East finishes sending the dot, his key rests on the back contact, connecting positive battery to the circuit at his end; West's key is still on the front contact and negative battery is still connected to the circuit at his end. Solution of the circuit problem by Kirchoff's laws shows that current flows down through P and up through P'. This will cause West's relay to pull over against the space contact, opening his sounder circuit and completing the dot which East sent. Since the current is up through East's relay, P', the armature will remain against the mark contact, keeping his sounder circuit closed. The sounder circuit should be closed since West has not completed sending the dash.

c. Complete circuit.—(1) *Equipment.*—Figure 29 shows the circuit from which the simplified diagram of figure 28 was made. The four 500-ohm resistances, a, b, c, and d, are the four windings of two retardation coils. The 2500-ohm resistances are the artificial lines: 300 ohms is the protective resistance in series with each generator. The 800-ohm resistances are the polar relays. In figure 29, there is added a piece of equipment not previously discussed. This



TL-926

FIGURE 29.—Bridge duplex system.

is the pole changer, by which marking and spacing is accomplished instead of by connecting the generators directly to the key contacts. It is not believed that the operation of the pole changer requires any explanation.

(2) *Reason for use of retardation coils.*—Each 500-ohm winding of the coil possesses considerable inductance, and consequently, a current coming over the line wire meets at first with great opposition in traversing the retardation coil winding, because of the counter electromotive force of self-induction which is developed in it. This electromotive force is in such direction as to assist in the rapid growth of current in the polar relay to a value momentarily greater than the steady value. This initial pulse of current through the relay causes its armature to be moved from contact to contact with great rapidity. The retardation coils do not hinder outgoing currents very much because equal currents pass through the winding of the coil differentially, and the magnetism developed in the core by one winding is neutralized by that developed by the other. Hence, the coils for this condition are noninductive.

40. Short-line duplex.—*a. Use.*—The great advantages of the short-line duplex lie in the fact that one of the stations requires very little equipment, no main-line generators, and a battery only sufficiently large to actuate a sounder. It is possible therefore to duplex a line from a large central station to a station at which it is uneconomical to maintain the costly generators required for the other types of duplex. This characteristic of the short-line duplex renders it very useful to the army, when it is desirable to work duplex with a large central station from a station in the field.

b. Circuit and operation.—(1) *Equipment.*—The circuit used is shown in figure 30. The large central station is West and the field station is East. The relay at West is called a differential neutral relay. (it is differentially wound but it is not polar; and excess of current in one winding over that in the other causes the armature to pull up regardless of the direction of the current). East's relay is an ordinary polar relay. The resistance of the artificial line, *AL*, is the same as the resistance from *x* to the ground at *G'*. The resistance of rheostat *r* is so adjusted that three times as much current flows through the line and East's relay when the key, *K'*, is depressed as when *K'* is opened.

(2) *Both spacing.*—If both keys are open, current flows from West's generator and divides equally at the midpoint of West's relay, since the resistance to ground from that point is the same through either path. Hence, West's relay is not energized, there being no resultant flux in the core. The direction of the current through the line and East's relay is such as to make the armature of the polar relay rest against the idle or space contact. It is seen that when both keys are open, both relays space, as they should.

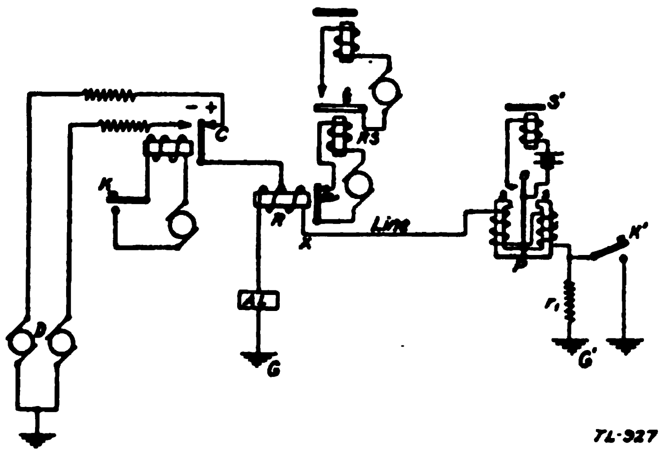


FIGURE 30.—Short line duplex system.

(3) *Both marking.*—If both keys are depressed, r_1 is shorted out and three times as much current flows in the right-hand winding of West's relay as in the left-hand winding. This excess of current in one winding energizes the relay and West's relay pulls its armature up to the marking contact. Depressing *K* has changed the direction of current through East's relay since negative generator is now connected to the line. The reversal of current in the polar relay causes its armature to move over to the marking contact.

(4) *One marking, one spacing.*—(a) Now suppose *K* to be depressed and *K'* to be open. Again current divides equally at the midpoint of West's relay and his relay is not actuated. The current through East's relay flows from ground to line and as this is a polar relay, the armature rests against the marking contact.

(b) If *K'* be depressed and *K* open, r_1 is out of the circuit. The direction of current through East's relay is such as to hold the armature on the idle or space contact. But three times as much

current flows in the right-hand winding of West's relay as in the left-hand winding; his relay is, therefore, actuated, pulling its armature up to the marking contact.

(5) *Repeating sounder.*—The repeating sounder *RS* must be used to eliminate false signals when *K* changes contacts while *K'* is being held down. When this occurs, the magnetization of *R* is reversed and therefore passes through zero. The zero magnetization allows the relay armature to fall back, closing the repeating sounder circuit. But the magnetization passes so quickly through zero that the current in the repeating sounder circuit does not have time to build up to a sufficient value to drag down the armature of the repeating sounder. Before the current in *RS* builds up, the magnetization of *R* is enough to pull its armature up and break the repeating sounder circuit again. Had the sounder been actuated directly by the armature of *R*, this delay could not have occurred and false clicks would have resulted. To aid in the operation, *RS* employs a heavy armature.

41. Questions for self-examination.—

1. What is duplex telegraphy?

2. What is the object of the artificial line?

3. What are the disadvantages of single-current duplexes?

4. Make a complete circuit diagram of a double-current differential duplex system of two stations.

5. What type of relay is used in a double-current bridge duplex?

6. What is the object of the retardation coils of the bridge duplex?

7 .What are the advantages of the short-line duplex?

8. Why must a repeating sounder be used?

SECTION VI

TELETYPEWRITER MACHINES

42. Purpose.—The teletypewriter is a machine operated type of telegraph communication. It is designed so that it can consistently maintain a high speed of operation. It may be used for telegraph communication from division headquarters back through the higher units, or between other points where a large amount of telegraph traffic is handled. One or more receiving stations may be operated from the same transmitter, producing a printed or typed copy of the message at each receiving station simultaneously.

43. Description.—Normally the teletypewriter installation consists of a keyboard similar to a standard typewriter keyboard and a typing or printing mechanism designed to print received messages either on a page as is done with typewriters or on a tape in the manner of stock quotation tickers. The page teletypewriter may type the message on separate sheets of paper or it may be equipped with a roll of paper from which the sheets may be torn at will. Several copies of the message may be made simultaneously with reception by inserting carbon paper between the sheets or in the roll of paper. At certain stations where receiving service only is required the keyboard may be omitted. On the other hand when a large volume of outgoing traffic is to be handled, a more elaborate sending mechanism in which messages are first recorded on a per-

forated tape and then run through an automatic transmitter may be used. Also at certain stations special characters may be placed on the keyboard and typing unit for the transmission of special information such as weather reports.

44. Operation.—In this section no attempt will be made to study in detail the design features or method of operation of each of the several types of teletypewriters, but consideration will be given to some of the general features applicable to all of them. Teletypewriter operation of telegraph service differs essentially from manual operation only in the substitution of sending and receiving machines (usually both within the same cover) for keys and sounders. Therefore, in the following discussion of the factors involved, circuits and examples of operation are taken from the manual system when the same factors apply to the teletypewriter system in order to simplify the explanation.

a. Code and signal composition.—(1) The signaling code used is not the Morse code of manual operation but a special one in which each letter or signal is made up of five units or elements of equal length. These units or elements are known as marking or spacing impulses. Marking impulses or signals are those impulses which operate the selector magnets of the printing mechanism of the teletypewriter. Spacing impulses or signals, which are the same length as the marking impulses, are those impulses that do not operate the selector magnets in the receiving machine. Two more impulses common to all code groups are necessary, and complete the code group for any letter, figure, character, or function, making a total of seven impulses to be transmitted. One of these impulses is a spacing impulse and is the first impulse sent, being used to set the receiving machine in motion and in readiness to receive the remainder of the code group. This impulse is the same length as the code impulses following it and is known as the start impulse. The other impulse, a marking impulse, is always the last impulse sent for each code group, and is used to return the receiving machine to a position of readiness to receive the start impulse just preceding the next code group. It is 1.42 times as long as any one of the other impulses and is known as the stop impulse because it stops the receiving machine in order to maintain synchronism. This will be explained more fully later.

(2) As illustrated in figure 31, the code provides for the letters of the alphabet, the numerals and several miscellaneous symbols

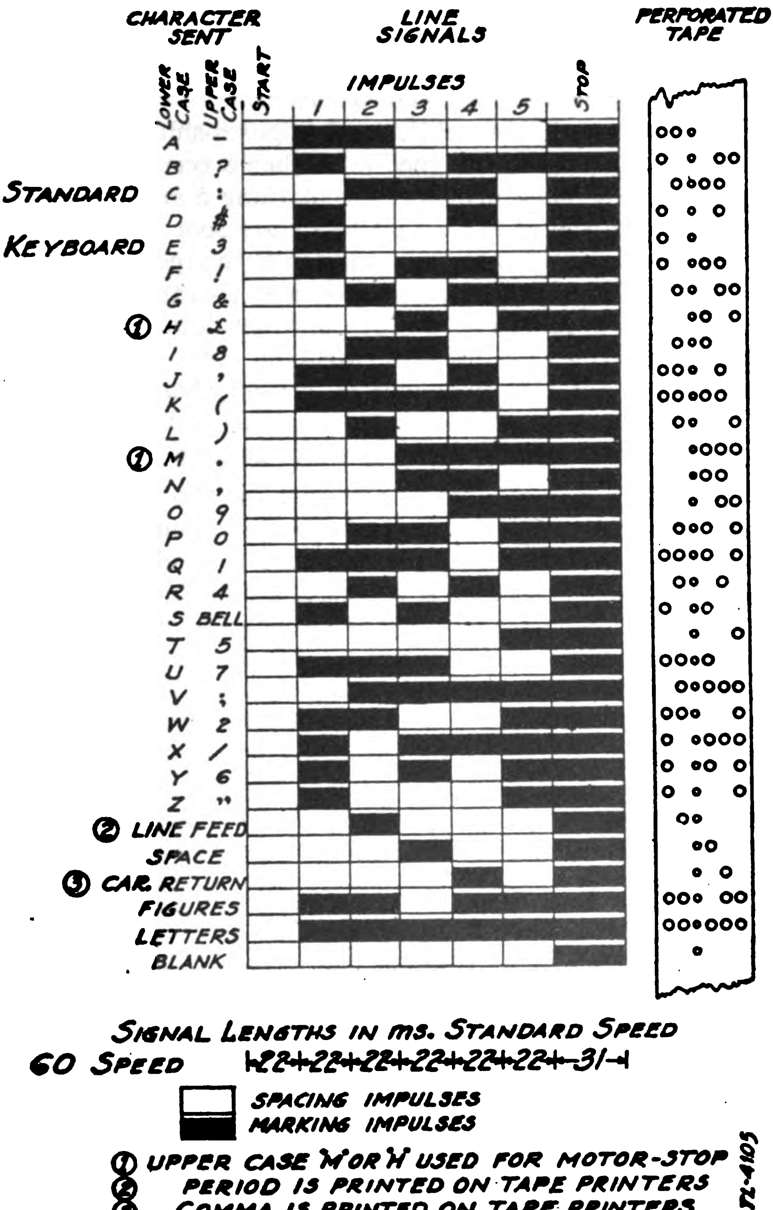


FIGURE 31.—Five unit teletypewriter code.

in common use or especially desired, as well as the special functions that the machines must perform, such as line feed, carriage return, and miscellaneous switching and signaling features. The provisions are made by using the 32 combinations that the 5-impulse code permit, including a "letters-shift" and "figures-shift" feature. The machine must then be so designed that when a certain letter key is operated at the sending machine, the marking and spacing signals corresponding to the code for that letter are sent out on the line; and when this signal combination comes in at the receiving machine, the corresponding type bar is selected and operated to print the letter. The code is known as the five unit permutation code and is sometimes called the five-impulse start-stop code. A six-unit code, which allows 64 different combinations, is used where it is necessary to transmit capitals, small letters, numerals, and punctuation or other marks or symbols for telegraph type-setting.

(3) Assuming some means is provided for the transmission of the desired impulses for a given code there remain two additional essential features for which provision must be made. First, and of vital importance, the sending and receiving machines must be kept in synchronism. That is, there must be a definite and constant time relationship between the operation of the two machines so that when No. 1 impulse is being transmitted from the sending machine, the receiving machine will be at the proper point in its operation to receive No. 1 impulse, and so on. Second, there must be a means of selecting the desired character in accordance with the incoming current impulses; this is sometimes effected by electromagnets but in recent machines is effected by purely mechanical means.

45. **Synchronism.**—Teletypewriters are synchronized by means of the start-stop system. The fundamental idea of this system is that the machines, instead of running continuously, shall be stopped after the transmission of each series of five impulses comprising the signal for one character. This insures that the two machines will be in exact synchronism at the beginning of every character; in other words, it corrects any existing timing differences so frequently that errors are not likely to occur. It requires, however, that two synchronizing current impulses be transmitted for each character in addition to the five selecting code impulses, a feature which necessarily extends the time required for the transmission of each character. There are several different designs of the controlling apparatus for start-stop systems. The oldest and perhaps

the most easily understood of these consist of a pair of commutators, the segments of which are connected to the line and the electrical elements of the sending and receiving machines, and are connected together periodically in a definite order by brushes rotating in synchronism and stopping at the end of each revolution. A simplified diagram of the sending and receiving faces of a pair of these commutator devices, known as distributors, is given in figure 32.

a. Selecting operation.—Figure 32 shows the circuit in the normal condition ready for the transmission of a character. Battery is supplied from ground at the sending station through the start-stop contact, center segment, and line relay of the sending station to the line and through the line relay to ground. Also a local battery at the receiving station supplies current through the mark contact of the line relay to the center segment of the receiving distributor. Since the circuit for the start magnet is held open at the line relay space contact the distributor arm is held stationary. These arms are connected to the motor through a friction clutch. When a keyboard key is depressed at the sending station the first thing that happens is that a set of sending contacts are closed to correspond to the code of the letter to be transmitted. Then the start-stop contact is opened momentarily. This opening of the start-stop contact opens the line circuit causing the line relays to release to the spacing contact. This closes the circuit at each station for the start magnets so that their latches are lifted and the distributor arms permitted to rotate. Since the motors are adjusted to approximately the same speed the distributor arms will remain in very close synchronism for one revolution. As the distributor brushes of the sending station passes over segment number 1 it connects contact number 1 to the line. If this contact is open both line relays will remain on their space contact, but if the sending contact is closed, battery will be connected to the line relays and the current will cause them to operate to their marking contacts. As the distributor arm of the sending station passes over the segments numbered 2, 3, 4, and 5, the distributor arm of the receiving station will be passing over its corresponding segments. When the receiving distributor arm is on segment number 1 the first selecting magnet is then connected to the mark contact of the line relay. If the line relay has been operated to its mark contact by current in the line, battery is connected to this contact causing

the first selecting magnet to operate. If the line relay is operated to its space contact no battery is connected to the selecting magnet and hence it will remain unoperated. This procedure is continued for segments numbered 2, 3, 4, and 5. At the sending station

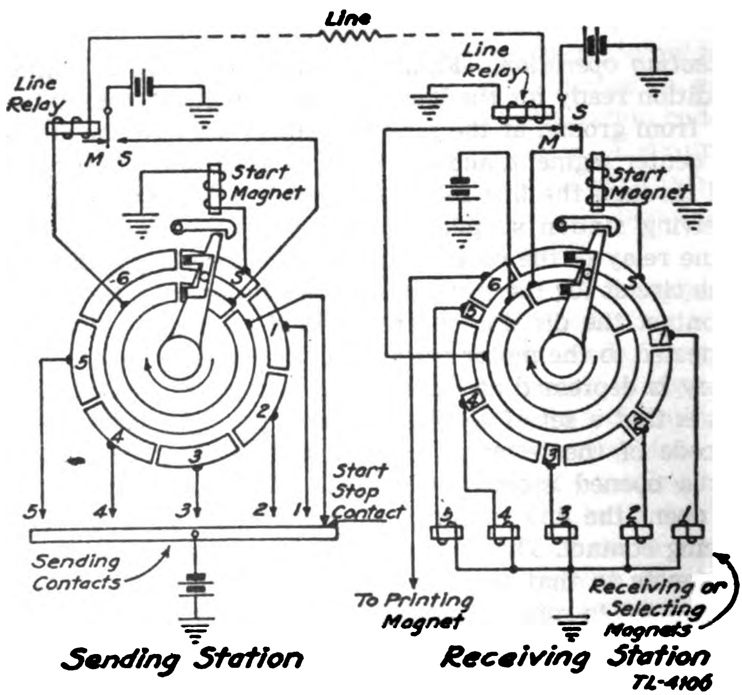


FIGURE 32.—Theory of start-stop system.

(through a mechanized arrangement) the start-stop contact, which has remained open during the transmission of the five impluses, closes as the distributor arm reaches the sixth segment. This causes both line relays to operate to mark, opening the circuit for the start magnet and, permitting the latches to catch the distributor arms and stop them. At the receiving station, as the distributor arm passes over the sixth segment, it connects battery to a printing magnet which prints the character set up by the selecting magnets. Both arms are stopped at the start segment and remain there until released by the opening of the start-stop contact

at the beginning of the next set of impulses representing a character.

It will be noted that the selecting segments of the receiving distributor are shorter than the segments of the sending distributor. This is to allow only the center of each impulse to be used, thus reducing the effects of distortion of signals.

46. Transmission in the modern machine.—In the modern machines the distributor is replaced by cams operating contacts in the proper sequence. The selection is also made through the use of cams so that the five selecting magnets and the printing magnet, shown in figure 32, have been replaced by a single selector magnet controlling the mechanized functions of the receiving mechanism.

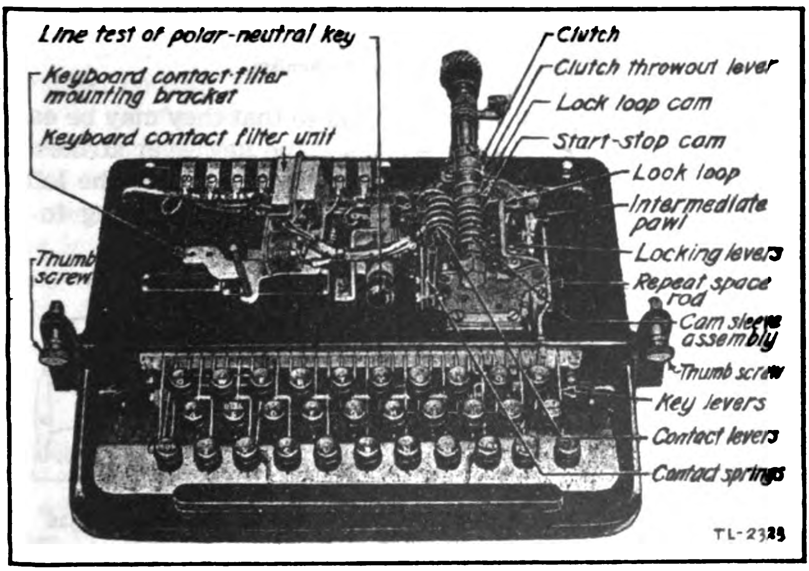


FIGURE 33.—Keyboard teletypewriter M-15.

a. Keyboard transmitter.—Figure 33 shows a view of the keyboard of the model 15 teletypewriter as used by the Army. Figures 34 and 35 show a more detailed view of the transmitting equipment.

(1) *Selector bars.*—Beneath the key levers are five selector bars and a universal bar extending across the width of the keyboard. The selector bars are provided with saw tooth notches (fig. 35) according to the requirements of the signaling code. These bars

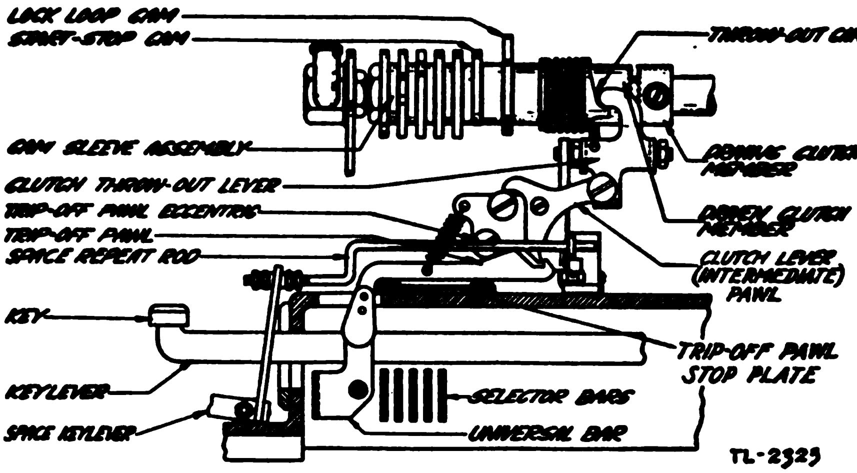


FIGURE 34.—Keyboard mechanism.

rest on rollers and are guided at each end so that they may be easily moved endwise. When a key is depressed the key lever strikes the slanting sides of these notches moving the bars either to the left or right, depending upon whether the impulses corresponding to the bars are to be marking or spacing.

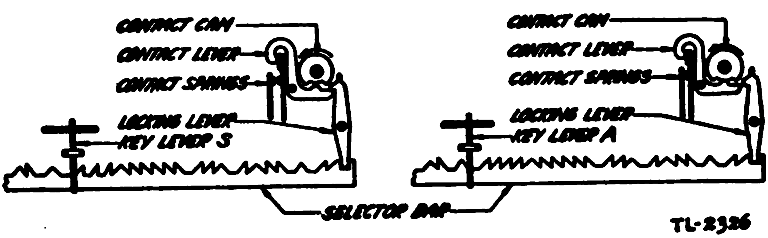


FIGURE 35.—Selector bar.

(2) *Universal bar.*—The universal bar (fig. 34), when operated, momentarily operates the clutch throw-out lever causing the driver clutch member to become engaged with the rotating driving clutch member. Thus, whenever a key or the space bar is depressed the selector bars and locking levers are set, and the universal bar is moved down, permitting the sending cams to start rotating.

(3) *Vertical locking levers.*—Each selector bar engages a vertical locking lever at its right hand extremity and positions it to

correspond with the signal impulses to be transmitted. Each locking lever controls the motion of a contact lever. If the upper end of the locking lever is positioned to the left, corresponding to a spacing impluse, it engages the contact lever and prevents it from rising into the indent of its cam as the cam rotates, thus holding the circuit open for that impulse. If the locking lever is positioned to the right, corresponding to a marking impulse, it does not interfere with the movement of the contact lever. Then, as the cam revolves, the contact lever rides on the cam surface and rises into an indent, thereby allowing its contact to close, sending out a marking impulse. As the cams rotate, the impulses, either marking or spacing, are transmitted in succession. It will be noted that there are five selector bars, locking levers, contact levers, and contact cams. In addition there is a start-stop cam with a contact lever riding on it. There is no locking lever associated with this contact lever. When the cam sleeve assembly is stationary the start-stop contact will be closed and all others open. When the sleeve is rotating the start-stop contact is opened and for a brief interval, representing the start impulse, there are no cam indentations in position to permit the closing of any contact. Then the first, second, third, fourth, fifth and start-stop cam indentations come into position for their contact levers to close their contacts unless restricted by locking levers. At the end of the revolution the clutch driven member is cammed out of mesh with the driving member and prevents the cams from rotating further until the next key is depressed.

(4) *Lock loop cam.*—The lock loop which is raised by the lock loop cam at the end of each revolution to allow the new combination to be set up is used while in its down position to prevent change in the selection set up (fig. 33). This is done by holding the locking levers in their set positions while the signals are being sent out. This arrangement also makes it impossible to depress another key until the signal for the previous character has been transmitted. All the pairs of contacts are connected in parallel and the group connected to the line for transmission.

b. Selection.—Figure 36 shows roughly the mechanical arrangement by which the received current impulses are translated to the code bars and figure 37 shows how these code bars determine the type character to be printed.

(1) *Starting of selection.*—When the receiving mechanism is ready to receive, the selector cam sleeve is held stationary by its

stop arm being caught on the stop lever which in turn cannot rotate because of the trip latch. The selector cam sleeve is connected to the drive shaft through friction clutches. Figure 36 shows only one selector lever, sword, "T" lever, and code bar though there are actually five of each. The projections of the selector cams on the cam sleeve are located at an angular displacement from each other as well as vertically displaced, so that each comes in contact with its selector lever as each of the five impulses are received. When the start impulse is received the armature is released and the armature extension moving the trip latch plunger causes the trip latch to release the stop lever which rotates to permit the stop arm to pass and the cam sleeve rotates.

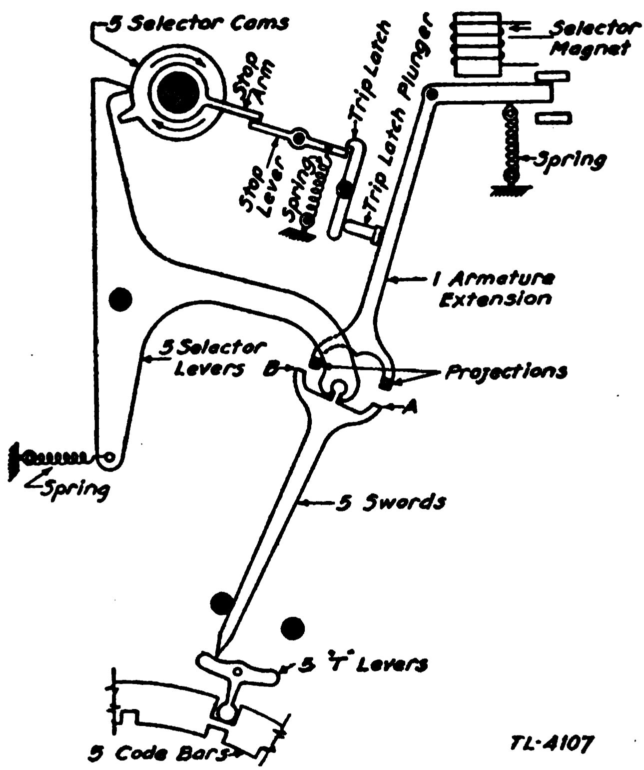


FIGURE 36.—Receiving mechanism of a single magnet teletypewriter.

(2) *Positioning of code bars.*—As the first selector cam comes in contact with its selective lever the first impulse will be received. If

the first impulse is marking, the armature extension will be moved to the right. At the end of the armature extension are two projections. When the selector lever is operated the sword is pulled back against one of the projections of the armature extension. If the extension has been moved to the right, the right side of the sword *A* will strike the right projection. The selector lever will pull the sword back a short distance further causing the sword to pivot around its right extension, moving its point to the left. Then as the selector lever rides off the selector cam projection the sword will be forced forward against the *T* lever rotating it and moving the code bar to the right. The next impulse will be received upon completion of the positioning of the sword. If the next impulse is spacing the armature extension will be to the left causing the second sword to be pointed to the right and moving the sword code bar through the action of its *T* lever to the left. This procedure is continued for each of the five swords and code bars. Following this the stop impulse will be received holding the armature extension to the right. This allows the trip latch to hold the stop lever so that as the stop arm completes its revolution it catches on the stop lever and holds the selector cam sleeve stationary until the next start impulse is received.

(3) *Printing of character.*—After the positioning of the code bars and before stopping, another cam on the sleeve caused the operation of the printing mechanism. Figure 37 shows the printing mech-

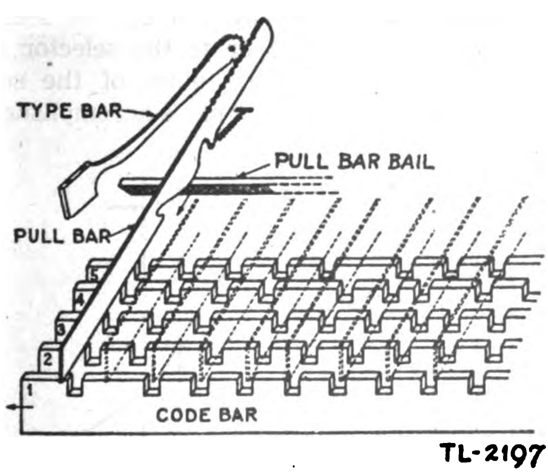


FIGURE 37.—Printing mechanism.

anism involved in the model 15 teletypewriter. As a result of the positioning of the code bars one set of notches in the code bars are lined up so that a pull bar may be permitted to drop into those notches. No other set of notches are so alined. Normally the pull bar bail holds all pull bars up off the code bars but in the operation of the printing mechanism the pull bar bail moves forward and this allows all pull bars to be lowered to rest on the code bars. One pull bar will drop into the set of notches properly alined. The pull bar bail will continue to move forward and will catch in the notch of this one pull bar pulling it forward also. As the pull bar moves forward the type bar is raised and the type strikes the paper, printing the character transmitted. At this point the pull bar bail returns to its normal position lifting all pull bars from the code bars so as to permit the repositioning of the code bars.

(4) *Selection of functions.*—The selection of the special functions of carriage return, line feed, etc., is performed in the same manner as for characters but for these particular code combinations there will be no alinement of notches to permit a pull bar to be operated and no character will be printed. However, the positioning of the code bars does cause the operation of other levers to produce the functions desired.

c. Orientation.—Due to the wave shape of the signals involved it is important that the small portion of the signal that is to be employed in the selection phase of reception should be from the section of the signal with the maximum strength. Thus, in figure 38, section B is obviously the one desired. It can be seen from this figure that in order to properly operate the selector mechanism, it is necessary to place the starting point of the selector cam sleeve in the most favorable position. This is accomplished by means

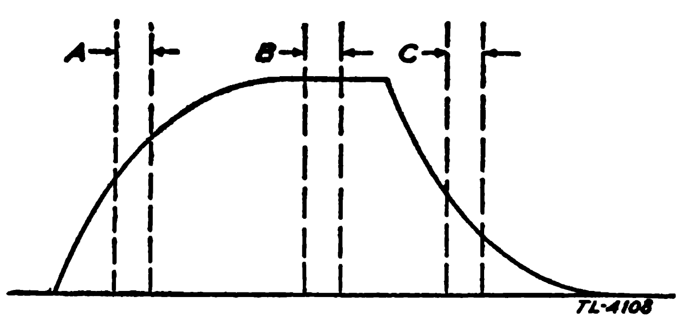


FIGURE 38.—Selection periods.

of the range finding mechanism, which is used to orient or take a range. This is reached through a hinged door in the left side of the cover to the teletypewriter.

(1) *Range finder mechanism.*—Mounted on the stop lever plate (which is part of the range finder mechanism) are the stop lever and the trip latch which may be rotated, thereby varying the relation between the start of the selector cam sleeve and the time the selector cam operates the selector levers. A graduated scale indicates the setting of the stop mechanism (range), and the thumb screw holds it in place after having been set.

(2) *Range measurement.*—The range is determined while receiving "RYRY" on the printer, by first moving the range finder index arm in one direction until errors appear and then back slowly until the errors disappear, and noting this latter position on the scale. In a similar manner, the other limit of the range is located by moving the index arm toward the opposite end of the scale. These limits represent the "range" of the machine, and should be at least seventy points apart, with the low point at twenty (20) or below (preferably between 15 and 20). This is so that allowable differences in adjustments will not materially affect the working range of the loop. The loop working range is between the highest of the low points and the lowest of the high points of all machines connected on the loop. The proper setting of each machine is the midpoint of these two limits. This applies to machines permanently connected in a loop. When connected to a switchboard the range should be measured while receiving from the switchboard and the midpoint of this range used as the final setting of the range finder mechanism.

d. Summary.—The types of mechanism employed vary considerably but are usually almost entirely mechanical. In general, the complete operation of teletypewriters may be divided into three parts:

(1) *Transmission.*—At the sending station, each operation of a key on the keyboard actuates a sending distributor to transmit the required signals, which consist of the start impulse, the necessary selecting pulses, and stop pulse.

(2) *Reception and selection.*—The signals transmitted are usually received by a line relay at each receiving instrument. This line relay controls the receiving mechanism which sorts out the pulses and selects the character to be printed.

(3) *Printing.*—After the selection has been made, the printing mechanism is actuated. The printing mechanism then prints the character, or performs the required function, and returns to normal position to await the next operation.

47. The M–15 teletypewriter.—The principles of operation just discussed apply to the model 15, 14, 26, and 19 teletypewriters. These machines differ only in the mechanical arrangement of the parts. The machine adopted as standard in the army is the M–15. In general appearance the M–15 resembles an ordinary commercial typewriter with a few additional keys or switches, and is known as a type bar page teletypewriter. A power switch located in the front right corner and projecting through a slot in the printer cover must be placed in the "ON" position before any message can be sent or received.

a. Keyboard.—The keyboard is similar to the keyboard of a standard commercial typewriter with a few exceptions as follows:

(1) Only capital letters and figures are used. There are no intermediate or small letters.

(2) To shift to the figures position, the key marked FIGS must be depressed.

(3) To unshift or return to letters position, the key marked LTRS must be depressed. Some machines are also arranged to unshift upon depression of the space bar.

(4) Operation of the key marked CAR RET causes the type carriage to be returned to the left hand margin of the paper.

(5) Operation of the key marked LINE FEED causes the paper to be advanced to the next line.

(6) On machines equipped with the automatic space repeat feature, the carriage continues to space as long as the space bar is held depressed.

(7) On the upper case of the S key, the word BELL appears. This is a signal bell and is used to summon the attendant at a distant station. First the FIGS key must be depressed. Then with the mechanism in figures position, the signal bell will ring once for each operation of the S kev. Where there are several stations on a single line, a code is usually agreed upon so that the sender may summon the attendant at any particular station.

b. Motor stop.—On the upper case of the *H* key, the word STOP appears. This means MOTOR STOP. On some machines, upper case *M* is used for MOTOR STOP. If the FIGS key is depressed and then

the *H* key, the printer motors of all the machines on the circuit will stop. To restart the motors, the SEND-REC-BREAK key must be depressed momentarily to the BREAK position. As soon as the SEND-REC-BREAK key is restored to the REC or SEND position, the printer motors of all machines on the circuit will start.

c. Test key.—Just below the sloping portion of the cover, there is a small hinged door which may be raised to provide easy access to the line-test key on the keyboard. With this key normal or *in*, the teletypewriter is connected to the line and anything written upon it will be reproduced on other machines on the line. With this key pulled *out*, an artificial circuit is provided for testing the machine locally without disturbing other machines on the line. This key is also sometimes arranged to permit the machine to be operated on either polar or neutral circuits. With the key *in*, it is connected for polar operation. With the key *out*, it is connected for neutral operation.

d. Platen.—In this machine the paper remains stationary while typing and the type basket moves across the paper from left to right. This is opposite from the normal typewriter conditions. When the machine is changed from LTRS position to the FIGS position, the platen with the paper is raised as in some types of typewriters. There is also a margin bell on the right margin as in the case of typewriters to give a warning when the right margin is approached. The margins, however, are not adjustable as in the typewriters.

e. Send-Receive-Break key.—The SEND-RECEIVE-BREAK key actually consists of two levers, one projecting out from the cover, the other extending to the edge of the cover only. When the longer lever is in the SEND position the machine will be connected for reception as well as transmission but if this lever is in the RECEIVE position the keyboard contacts are shorted and reception only is possible. This lever cannot be operated to the BREAK position unless the shorter locking lever is also moved to that position. When this is done the circuit is opened, causing all machines connected in this circuit to "run open." This procedure is often used to break into the transmission from a distant station. The send-receive switch on all other machines in the circuit will be thrown to the receive position automatically when a break is transmitted. It must be manually restored to SEND in order to transmit.

f. Blank key.—One key on the keyboard is blank and has no character on it. In some machines operation of this key once causes the send-receive switch to be operated to the receive position. This will

lock out the keyboard of all machines so equipped. However, some machines are so arranged that this blank key must be operated twice in order to lock out the keyboard. This arrangement is often required since in some instances motor-stop operates from the combination FIGS-BLANK-STOP and a single operation of the blank key must not kill the keyboard.

48. The M–14 teletypewriter.—This teletypewriter is known as a type bar tape teletypewriter and is similar to the M–15 except that it types upon a tape. The arrangement of the equipment is such that the tape passes just above the keyboard so that it is readily visible to the operator. This machine is found only at special installations in the army.

49. The M–26 teletypewriter.—The M–26 teletypewriter differs from the M–15 as follows:

a. There is no line test key built into the machine.

b. In this machine, the platen and paper move from right to left when typing as in the case of the regular typewriter.

c. The platen does not change position when shifting from LTRS to FIGS. This is taken care of in the typing mechanism.

d. The type instead of being arranged in the form of a type basket as in a typewriter, is mounted as pellets on a type wheel. This wheel is revolved until the correct type pellet is in position and then a printing hammer strikes the pellet to type the character.

e. The machine is smaller and makes less noise than the M–15.

f. It is not as sturdy as the M–15 and for this reason is not the standard type accepted by the army.

g. Where the M–15 is also adaptable to sprocket feed whereby many copies of forms may be typed, the M–26 cannot be so adapted, though it is capable of making carbon copies of messages.

h. The M–26 cannot use a tabular mechanism as can the M–15.

i. The M–26 does have the advantage of costing only about half that of the M–15.

j. The selector mechanism on the M–26 is located on the top of the typing mechanism and cannot be reached without taking off the cover of the machine.

k. The power switch is located on the table instead of on the machine. This is in reality three switches, each a single-pole double-throw switch. They are fastened together in such a way that a three-pole double-throw switch is formed. When this switch is in

the OFF position, the a-c power is turned off and the line has a short placed on it instead of the printer circuit.

l. The SEND-REC-BREAK switch does not appear on the M-26 and it is always in the SEND position where it will both send and receive. A BREAK switch in the form of a button is located on the base to the left of the keyboard. By pressing this button, the circuit is opened and the break signal transmitted.

m. Both the M-15 and the M-26 may be set to double space if desired and both may be equipped with motor-stop mechanism.

n. The M-26 does not have a blank key.

50. The M-19 teletypewriter.—The M-19 teletypewriter actually consists of an M-15 teletypewriter with the addition of three units, a tape perforating mechanism, a character counter and a transmitter distributor. In addition, a reperforator may also be installed as an additional unit if the traffic warrants. The tape perforating mechanism, character counter, and the keyboard and base of the teletypewriter are made up in one unit and termed the teletype M-15 perforator transmitter.

a. Keyboard control lever.—A manually operated, three-position keyboard control operating lever, mounted on the right side of the unit, permits the operator to select any one of the following methods of operation:

(1) Operating lever in upper or keyboard position.—Direct keyboard transmission to the line with a printed record being produced at the transmitting point. The maximum speed of the keyboard is limited to the predetermined speed of the set.

(2) Operating lever in middle or keyboard and tape position.—Simultaneous direct keyboard transmission to the line and perforation of tape with a printed record being produced at the transmitting point. The maximum speed of the keyboard is limited to the predetermined speed of the set.

(3) Operating lever in lower or tape position.—Perforation of tape only with the associated printer either receiving messages from a distant station, or monitoring the message perforated in the tape as it is being transmitted to the line. The indicator on the character counter moves each time a character key is depressed. The counter is provided with a signal lamp to indicate when the end of a line is being approached. The maximum speed of the keyboard in this case is not limited to the predetermined speed of the set and the operator may, therefore, perforate tape at speeds much greater

than the speed at which a tape transmitter would send to the line.

(4) Operating lever in middle or keyboard and tape position and line test key in test position.—It is also possible to perforate and print a home record without transmitting directly to the line when the test key (located near the center of the keyboard) is in the test position. This method is helpful in preparing perforated tape for use in connection with printer forms. The maximum speed of the keyboard is limited to the predetermined speed of the set.

51. The keyboard tape perforator.—The keyboard tape perforator is a mechanism that perforates a tape as shown in figure 31. This is a small machine with keyboard and tape perforator but without the associated teletypewriter. Thus, if all teletypewriters are busy, tape may still be perforated and later sent out over the transmitter distributor. A hole is punched for a marking pulse and the paper left intact for the spacing pulse. The line of smaller holes down the center of the tape is used to feed the tape through the the machine. This unit, which is the same as the keyboard and perforator position of the M-19, is not operated by a motor but is entirely mechanical with an electromagnet operating the punches as set up by the key levers.

a. Back space lever.—A back space lever is provided for moving the tape backwards for the correction of errors. When this lever is moved from left to right, the tape is moved back one position and then the letters key may be depressed, causing five holes to be perforated over the error. This combination may be passed through the tape transmitting device without printing any character or letter on the receiving printer. However, if a character in the upper case is removed it will be necessary to strike the shift key again, because the "letters" combination will unshift the receiving printer.

52. The transmitter-distributor.—This machine is a motor driven, combination tape transmitter and distributor. Its purpose is to translate the code combination, perforated in the tape, into electrical impulses and transmit these impulses to the receiving station. There are two types of distributors of this class—one operates on the five unit code and the other on the six unit code. The two, however, are almost identical, the only difference being that the six unit type has an additional contact, lever and commutator segment to take care of the additional sixth unit. The tape transmitter, utilizing the perforated tape, sets up the code combinations to be transmitted. The commutator distributor sends the code combina-

tion out over the line as marking and spacing impulses, in proper sequence and at a predetermined speed. The two units are driven together by either a governor-controlled motor or a synchronous motor operating at a constant speed.

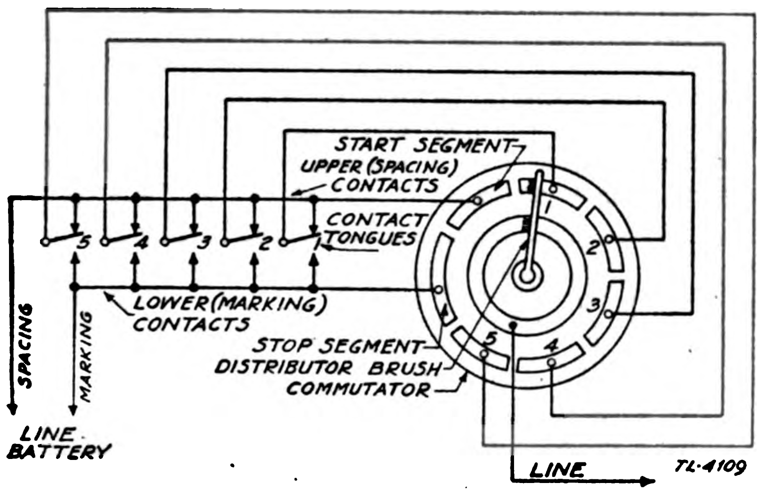


FIGURE 39.—Simplified circuit of transmitter-distributor.

a. The commutator.—The commutator is made up of two concentric conducting segment rings attached to an insulating disc. The outer commutator ring is composed of seven segments. Five of these segments correspond to the five intervals of the code. Immediately preceding the No. 1 segment is the "start" segment, while the segment following No. 5 is the "stop" segment. (See fig. 39.) When the brush passes over the start segment, a spacing impulse is always transmitted, whereas a marking impulse results when it passes over the stop segment. These two invariable impulses cause the receiving mechanism to operate in unison with the distributor brush arm. The inner commutator ring is a solid ring which is connected to the line, and as the distributor brush arm revolves, it connects the segments of the outer ring successively to the line.

b. Transmission.—As indicated by the wiring diagram (fig. 39), the five tongues on the tape transmitter move between the upper and lower contacts, called the "spacing" and the "marking" contacts respectively. The perforations in the tape determine which contact tongues will be on spacing and which on the marking con-

tacts. When the distributor brush is on the stop segment, no signals are transmitted and marking current is sent to the line. At such a time, the selector at the receiving terminal will be held at rest. To transmit a combination of impulses, the distributor brush revolves in the direction indicated. It will first pass over the start segment, sending a spacing impulse over the line. This impulse starts the receiving mechanism. Each of the five code segments of the distributor is connected by a contact tongue to either an upper (spacing) or lower (marking) contact, depending on the character of the signal to be sent. As the brush revolves, it will successively connect the five code segments to the line, each in turn sending out a marking or spacing impulse. Finally, the brush reaches the stop segment again and sends out the stop impulse

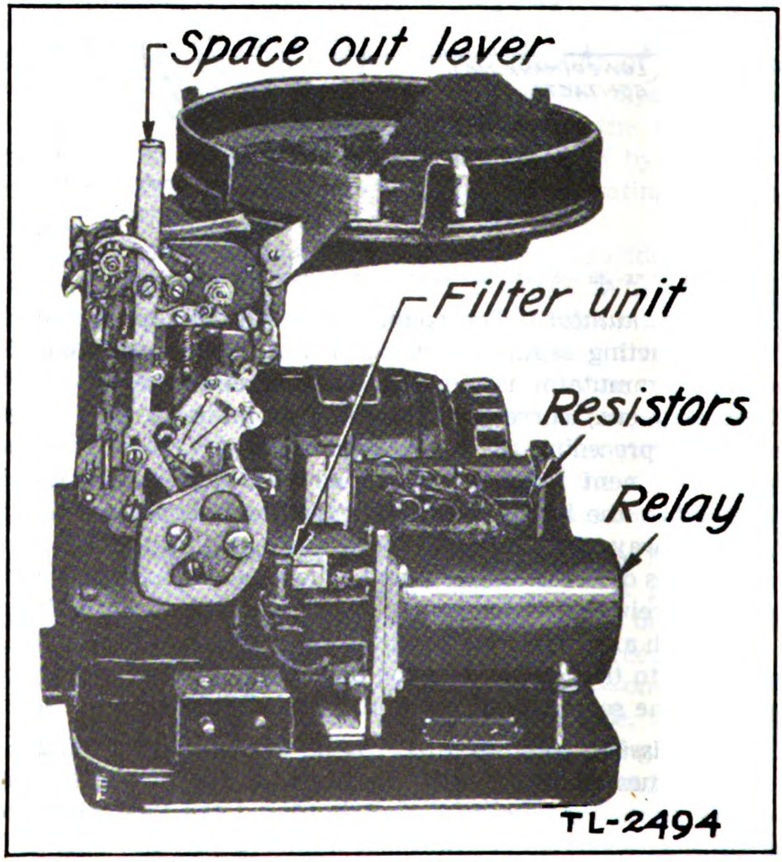


FIGURE 40.—Reperforator.

which stops the receiving mechanism. This start-stop system keeps the receiver in synchronism with the distributor.

53. The reperforator.—If a message is to be relayed through a station, there are three ways it might be done; it might be received on a printer and retransmitted by an operator on another M–15 machine, or it might be received on an M–15 and then with a perforator make a tape and run through a tape transmitter-distributor. But both of these methods require too much time and require an attendant to perforate the tape. The third method is by means of the reperforator (fig. 40). This is a small machine which receives the electrical impulses and, converting them into mechanical operations, perforates a tape which may then, at any time, be run through a tape transmitter-distributor for retransmission. This requires very little attention from the operator. Where the traffic warrants, the reperforator will be used. As an average, one will be used with every two M–19 teletypewriters.

54. Questions for self-examination.—

1. The teletypewriter consists of what two major mechanical parts?
2. How does the teletypewriter code differ from the Morse code?
3. What special functions must be provided for in the code besides the letters of the alphabet and numerals?
4. What system is used to synchronize teletypewriters?
5. Why is it necessary to use such a system instead of synchronous motors on the machines?
6. What is the nature of the start and stop impulses?
7. In the modern machine how many magnets control the selection and printing of a character?
8. How many distributors are employed in a complete M–15 printer?
9. What is the purpose of the vertical locking levers?
10. What is the purpose of the lock loop?

11. What is the purpose of the line test key?

12. What is meant by orientation?

13. How is the range determined on a teletypewriter?

14. What is meant by the word STOP appearing on the H key?

15. What is the function of the SEND-RECEIVE-BREAK key?

16. How does the M–14 differ from the M–15?

17. How does the M–26 differ from the M–15?

18. Of what is the M–19 composed?

19. What is the effect of the keyboard control lever upon the operation of the M–19 machine?

20. Explain the use of the keyboard tape perforator.

21. How does the transmitter-distributor convert code perforations to electrical impulses?

22. What is the purpose of the reperforator?

Section VII

TELETYPEWRITER CIRCUITS

55. General facilities employed.—Various types of circuits are used in connection with teletypewriter operation. Open wire or cable may be used and the means by which telegraph channels are secured will, except in rare cases, be by means of superposition. That is, the telegraph channel will be obtained from a given wire or wires in addition to those wires being used for telephone service. This superposition may be by simplex of a physical circuit (SX), simplex of a phantom circuit (SXP), physical or side circuits composited (CX), or a phantom circuit composited (CXP). These methods are represented in figure 41 and are covered in more detail in section II.

56. Basic teletypewriter circuits.—Basically a teletypewriter consists of two fundamental electrical units. The receiver mechanism electrically consists of the selector magnet with its leads brought out to terminals and may be compared to the common sounder as employed in Morse telegraphy. The transmitting mechanism electrically consists of the keyboard or transmitting contacts with leads brought out to terminals and may be compared with a telegraph key which has the circuit normally closed but is opened upon pressing the key, such as an open-circuit type of key using the back contact instead of the front. This "key" and "sounder" of the teletypewriter may be connected into any circuit, neutral, duplex, polar, or otherwise, in which such a Morse key and sounder would be used. Their use in the more complex circuits of course call for the use of relays and the requirement here is that the relay be capable of

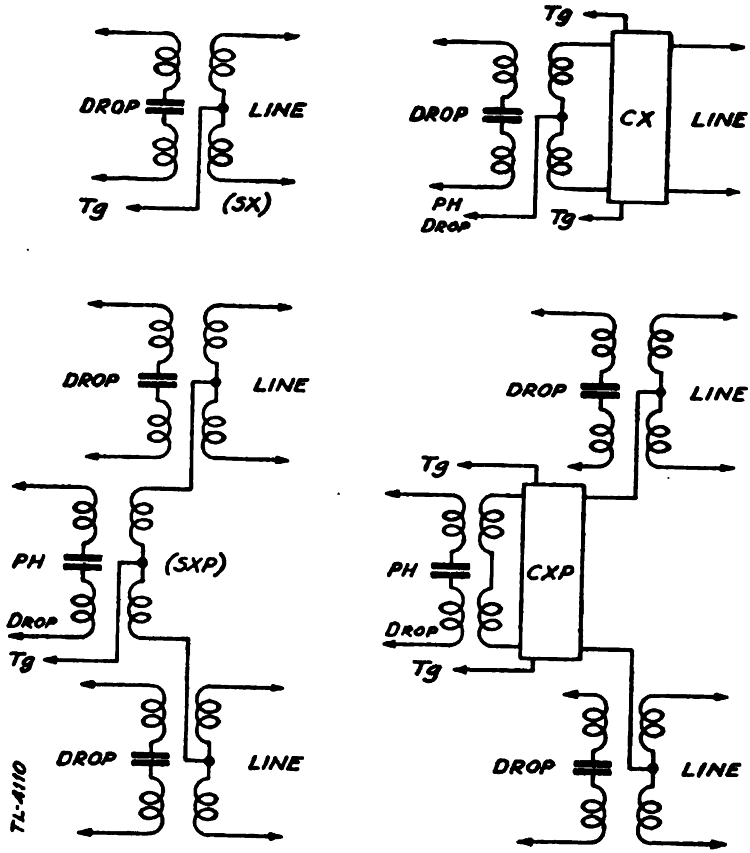


FIGURE 41.—Methods of obtaining telegraph channels.

accurate response to the high speed telegraph signals to be transmitted. Likewise the circuit constants should offer a minimum of distortion to the signals being transmitted.

a. Direct neutral connection.—The simplest connection of teletypewriters is as shown in figure 42. Here the selector magnet is connected with the transmitting contacts in series with the line. If ground return is to be employed one of the line connections shown in figure 42 would be connected to ground while the other would go to the telegraph line circuit. Two or more machines may be connected in a circuit by connecting them in series. Line current is supplied by a direct current power source as discussed in paragraph 59.

b. Use of single-wound relay.—Though the teletypewriter will work satisfactorily in the circuit as shown in figure 42, it may be worked satisfactorily over greater distances and over poorer line facilities by employing the use of a relay. If a single-wound, neu-

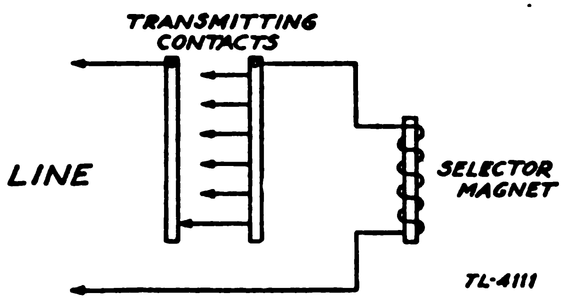


FIGURE 42.—Simple neutral connection.

tral type relay is to be used the circuit will be that of figure 43. In this circuit the selector magnet is removed from the line circuit and connected in a local circuit in series with a direct current power source and the mark contact of the relay. The relay winding is connected in series with the transmitting contacts in the line. With the

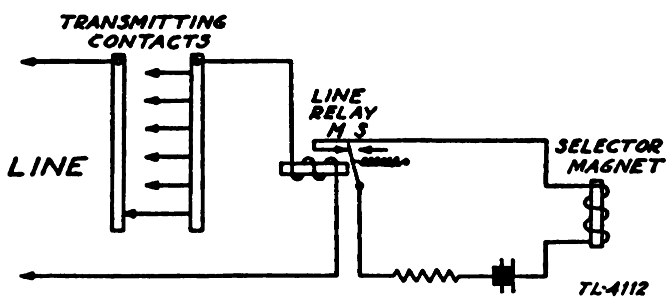


FIGURE 43.—Use of single-wound relay.

line circuit closed, the line relay will be operated to its mark contact. This closes the local circuit and operates the selector magnet.

c. Use of double-wound relay.—Figure 44 shows the circuit employed when the double-wound type relay is used as a line relay. This circuit differs from that of the single-wound relay circuit only in the addition of the bias winding circuit consisting of the bias winding, a current limiting resistance and a source of direct current.

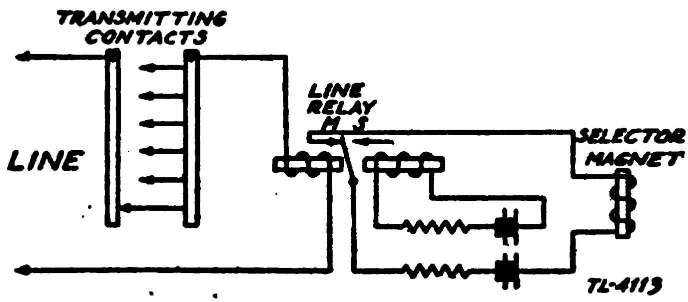


FIGURE 44.—Use of double-wound relay.

As shown in figure 44 separate power sources are required for the local circuit, bias circuit and the line circuit. A single power source

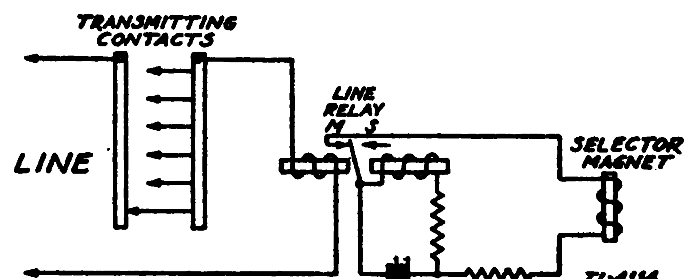


FIGURE 45.—Common power supply.

may be used as shown in figure 45 for bias and local circuits. By connecting the line circuit through this same power source, line current may also be supplied without additional power source providing the available power source has sufficient capacity.

57. Wiring of teletypewriter.—The wiring for the individual components of the teletypwriter is brought out to terminal strips in the machine so that they may be connected in whatever type of circuit that is to be used. The wiring differs in the different types of teletypewriters and reference should be made to the technical instructions furnished with the individual machines for details of wiring. The break key which is also brought out to a terminal strip is normally wired in series with the transmitting contacts.

58. Motor circuits.—The motors employed in teletypewriters are of two general classifications: (1) synchronous with speed constant, and alternating current supply required; (2) the governed type

ith speed adjustable and either alternating or direct current ipply necessary depending upon the individual motor.

a. Synchronous motor.—Figure 46a shows the circuit involved ith the use of a synchronous motor. The centrifugal switch is losed at the start, connecting the start winding into the circuit, but s opened when the motor nears its proper speed. If the motor stop ontrol is not desired the motor stop control contacts are shorted ut. A capacitor is placed across this switch and motor control

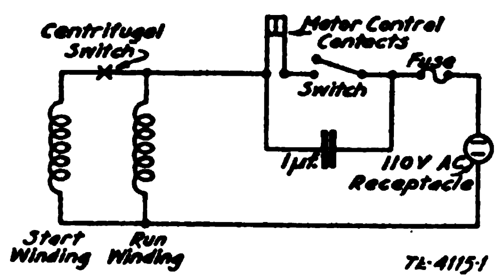


FIGURE 46a.—Synchronous motor.

contacts to reduce arcing when the switch or contacts are opened. Teletypewriters equipped with synchronous motors may be operated only where there is an alternating current supply having a voltage and frequency corresponding to the rating of the motor used.

b. Shunt d-c motor.—Where only direct current is available for running the motor a shunt direct-current motor may be used as shown in figure 46b. This motor is of the governed type. The governor contacts are controlled by the speed of the motor. At the

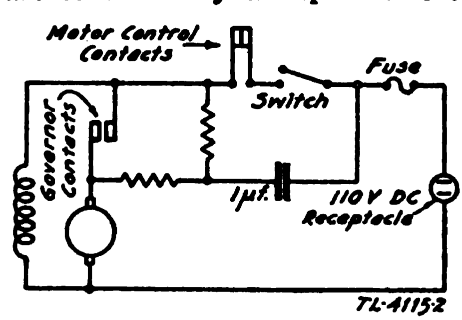


FIGURE 46b.—D-c shunt motor.

start the contacts are closed but as the motor speed rises above the proper speed they open to insert a resistance in series with the

armature circuit, decreasing the current through the armature and thus decreasing the motor speed.

c. Speed adjustment.—There are several methods of adjusting the speed of the governed motors of teletypewriters. The fan wheel of the motor has black and white lines marked around its rim. A tuning fork is provided which has small vanes fastened to the ends of the prongs and pointing toward each other. As the fork is vibrated the vanes move back and forth opening and closing the gap between them. The motor speed is adjusted so that, when the rim of the fan wheel on the motor is observed through the slit between the vibrating vanes on the tuning fork, the black and white lines appear to be stationary. However it is possible to adjust the speed of the motor without a tuning fork. With a sixty word per minute printer it requires 0.163 second for the transmission of each character. The margin bell on the teletypewriter should ring when 66 characters have been printed from the left margin. If the carriage is returned to the left margin and the space bar is held down for continuous spacing the margin bell should ring at slightly more than eleven seconds. When calculating the time it should be remembered that there will be a mechanical time lag of approximately two spaces between the time when the bell is tripped and when it rings. The speed of the motor may be adjusted until this time is correct.

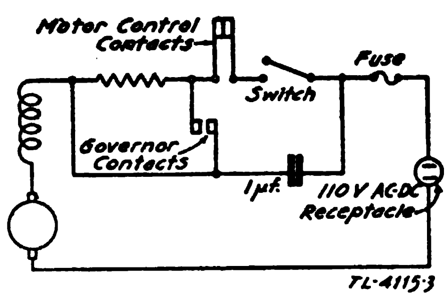


FIGURE 46c.—Series a-c d-c motor.

d. Series a-c d-c motor.—Figure 46c shows the circuit for a series motor. Here the armature and field are in series and the governor again inserts resistance in series with the armature (and field) to reduce the speed and cuts it out to increase the speed.

59. Power supplies.—If an external power source of direct current is available and a direct-current motor is used, this direct-current power source may be used to supply the current for the local cir-

cuits as well as line current. However, if alternating current is the only power available, then some means must be used to convert this alternating current into direct current to supply the local and line currents. A motor-generator set may be used to supply the necessary current, or a rectifier may be used. Figure 47 shows the circuit of the more common type copper-oxide rectifier. The sec-

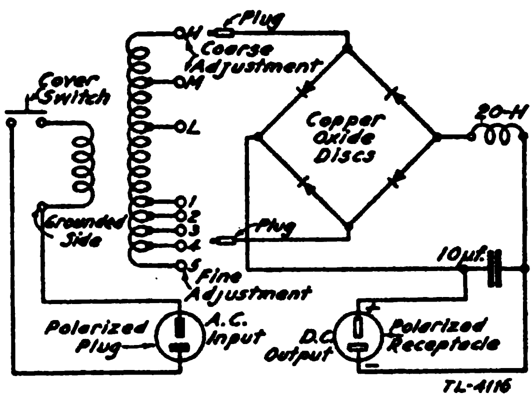


FIGURE 47.—Rectifier circuit.

ondary of the transformer has taps brought out so that the output voltage of the rectifier may be adjusted to its proper value. The copper-oxide rectifier operates on the principle that if two dissimilar metals are in contact, current can flow between them more easily in one direction than in the other. Copper and copper oxide are used in the same manner as two dissimilar metals, to form the elements of the copper-oxide rectifier. This combination offers low resistance to current flowing from the copper oxide to the copper, but offers a very high resistance to the flow of current from the copper to the copper oxide. Thus it becomes of value for the rectification of alternating currents. In figure 47 the triangle represents the copper oxide and the straight line represents the copper, thus indicating the direction of the current flow through the circuit.

The output of the rectifier is passed through a filter to smooth out any ripples. While the motor of the teletypewriter might operate on either direct or alternating current, depending upon the design of the motor, the local operating circuits and the line circuits require direct current. This may even be supplied from batteries. Line current should normally be adjusted to 60 milliamperes. The current may vary materially from this value and still maintain

satisfactory operation. The permissible current variation depends upon the constants of the circuit. The current required in the selector magnet, bias circuit, or other circuits that might be connected will vary with the type of equipment used. The value of these currents may be obtained from the technical data furnished with each teletypewriter.

60. Questions for self-examination.—

1. What type of facilities may be employed for teletypewriter circuits?

2. What pieces of Morse equipment might be used to represent a teletypewriter?

3. What is the simplest circuit for connecting a teletypewriter in a line?

4. How may three machines be connected in a circuit?

5. Draw the circuit for a teletypewriter using a double winding line relay with common battery supply for local and line currents.

6. How may speed of a governed teletypewriter motor be adjusted?

SECTION VIII

TELEGRAPH REPEATERS

61. Principle of repeaters.—Previous sections have shown the satisfactory operation of a properly adjusted relay depends upon the reception of the proper amount of current through its coils and upon the amount of distortion the signal picked up in transmission. These factors depend, in turn, upon the length of the line and its constants. Where a line is so long that the line constants prevent satisfactory operation, it may be cut in the middle and made into two independent circuits, each of which is short enough to operate. Call these independent circuits *A* and *B*. Now an operator located at the midpoint could hear signals made by the operator at the distant end of *A* and could transmit them to the operator at the distant end of *B*. He would be repeating the message, or as we usually speak of it, relaying the message. The repeater is simply an electro-mechanical device to take the place of an operator at the midpoint. It repeats the signals received from *A* to *B*, simultaneously with the reception.

62. Duplex repeaters.—Since duplex repeaters are more easily understood than the single-line repeater, the polar direct-point repeater will be explained first.

In figure 48 are two independent double-current duplex circuits. Designate the two end stations as East and West, and the common station from which the lines run to East and West as Center. Disconnect Center's left hand line from the key and connect it to the armature of Center's right hand relay; connect positive and negative battery to the space and mark contacts, respectively, at Center's right hand relay.

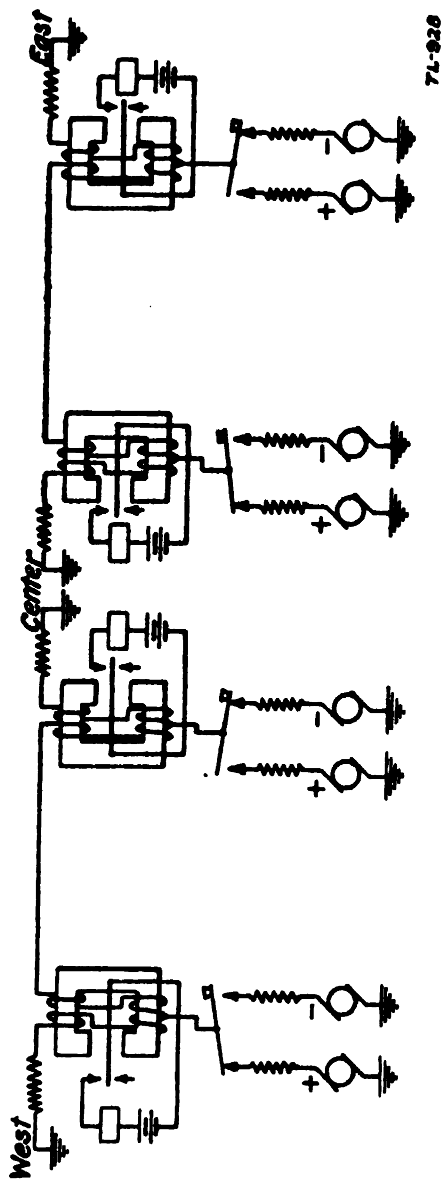


FIGURE 48.—Two independent duplex systems with common location of one terminal.

Then perform a similar operation with the right hand relay line and contacts at the left hand relay. The result is shown in figure 49; it is a polar direct-point repeater.

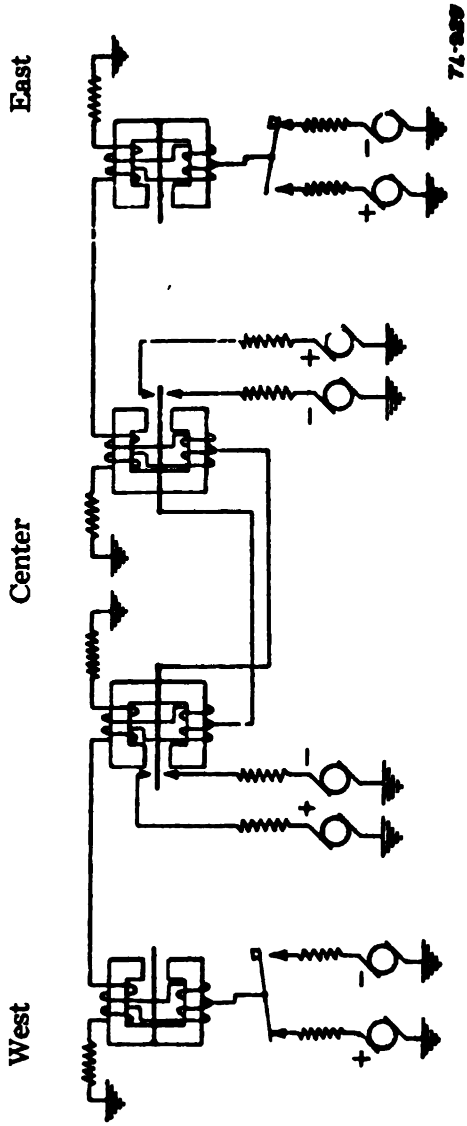


FIGURE 49.—Polar direct-point repeater.

When West depresses his key, Center's left hand relay pulls its armature to the mark contact. This connects negative battery to the right hand line and causes East's relay to pull up to the mark position. The signal made by West has been repeated to East. The action in all cases is exactly like that explained under differential duplex.

63. Single-line repeaters.—*a. Closed-circuit system.*—In a neutral system where the receiving operator must be able to break in on the transmitting operator, a device that will repeat the signal in both directions is not so simple as the polar direct point repeater. The theory of this device can be understood best by studying its operating features step by step. First let us suppose that two intermediate relays are connected into a simple circuit as shown in figure 50a, with the winding of one relay in series with the contacts of the other and vice versa. It is evident from a study of figure 50a that this circuit does not meet the requirements of a repeater. It is a step in the right direction, but opening either key will result in opening both circuits at the intermediate station and the closing of either or both keys cannot restore the contacts of the R_W and R_E relays. In order that this device shall function it is necessary to add to each relay an additional coil so wired that its own armature will be closed while the armature of the other relay is released, regardless of circuit condition of its own main windings. These coils

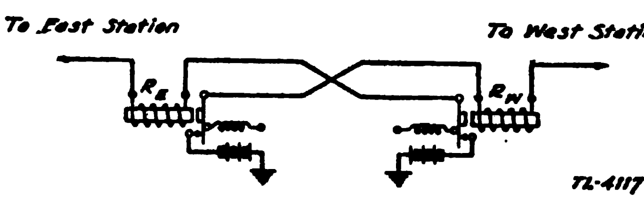


FIGURE 50a.—Telegraph repeater line circuit.

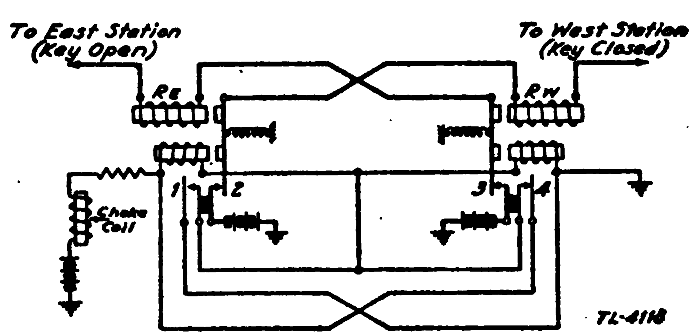


FIGURE 50b.—Single Morse repeater circuit.

are called holding coils and figure 50b shows the holding coils added to the circuit of 50a. The battery for the holding coils is a local one and is not connected to the line in any way. It is repre-

sented by light lines to distinguish it more clearly from the main line telegraph wires. The two holding coils are in series and each line relay is equipped with an additional set of contacts that shunt the holding coil of the other relay when closed. The resistor in series with the local battery is to limit the current flow when the holding coils are short-circuited, and the induction coil quickens the action of either holding coil when the shunt is removed. The operation is now as follows: when both East and West keys are closed, the main line coil holds the armatures of both relays R_W and R_E to the mark position and both holding coils are shunted out through the contacts *1* and *4*. Now suppose the East operator opens his key. The main line relay of R_E will be de-energized and the armature will be moved to the space position by a spring, breaking contact *1* and *2* and repeating the space signal to the West operator. When contact *1* is broken, the shunt on the holding coil of R_W is removed at the same instant the main line coil is de-energized and the energized holding coil holds the armature to the closed position. The armature of R_W is held closed by the holding coil while the East operator is spacing. When the East operator closes his key, the main line circuit through R_E will be completed and the main line coil will pull the armature back to the marking position, closing the contacts of R_E which close the main line circuit of the West station and shunt the holding coil of R_W so that both armatures are again under the control of the operator's keys. If the West operator desires to break while the East operator is sending, he merely opens his key. As the East operator continues to send, the next signal that closes his circuit, and shunts the holding coil of the R_E relay, will render this holding coil inoperative and permit the R_W armature to move to the space position, breaking the East operator.

b. Open-circuit system.—The repeater described above cannot be used on the open-circuit telegraph system. However, an open-circuit repeater is a very simple device and can be constructed quickly using two neutral relays with front and back contacts and a battery. A circuit diagram of an open-circuit telegraph repeater is shown in figure 51. Like the closed-circuit type in figure 50b the winding of one relay is in series with the contacts of the other. On the front contacts battery of sufficient capacity to operate the system is connected. The operation of the repeater is as follows: when the circuit is idle with both keys open (back contacts closed) the armatures of R_E and R_W are held on the back contacts by the springs, closing the line circuit through the relay windings to ground. No

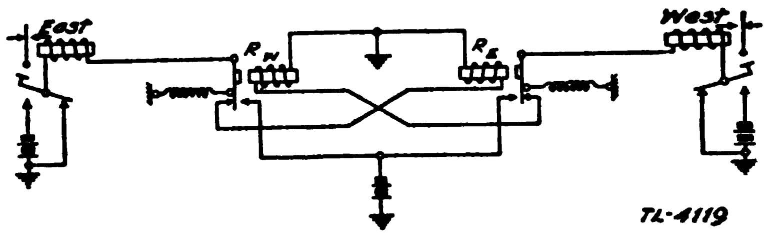


FIGURE 51.—Open-circuit repeater.

battery is in this circuit, therefore, the relay windings are deenergized. Now suppose the East operator closes his key. The relay R_E will now receive current from the East battery and become energized, closing its front contacts. Since battery is connected to the front contact of the R_E relay, current will flow in the West circuit and the signal will be repeated to the West operator. Should the West operator desire to break, he merely closes his key. As East continues to send, the next spacing signal will give the West operator control of the R_W relay.

64. **Regenerative repeater.**—The high speed operation commonly used with teletypewriters is possible only if the received signals are free from any large amount of distortion. Since telegraph signals are invariably distorted to some extent in the process of transmission and since the ordinary telegraph repeater repeats the greater part of such distortion so that it increases cumulatively with the length of the over-all circuit, the maximum distance over which a teletypewriter circuit will operate tends to be limited by this factor. Fortunately, the fact that the signals are of standard length and are transmitted with mechanical uniformity permits the use, in long circuits, of a special type of telegraph repeater, which is capable of eliminating distortion from the signals. This is known as the start-stop "regenerative" repeater. The principle of the regenerative repeater is based upon the operation of a transmitting machine by a receiving machine. The receiving mechanism, instead of typing the message, sets up the code for the transmitting machine which relays it to the next section of the circuit simultaneously with reception. Consisting essentially of a sending and receiving drum or distributor similar to those used in the teletypewriter mechanism, it is capable of receiving without error any set of signals that would be satisfactorily received by an ordinary teletypewriter, and of sending these same signals out as free from distortion as the signals formed by the sending set. Therefore, by spacing regenerative repeaters at intervals that would be sufficiently short

for satisfactory operation of a standard teletypewriter circuit, it is theoretically possible to operate a circuit of any length whatever.

65. Questions for self-examination.—

1. What are the factors limiting the distance over which telegraph will work on a single line?

2. Why are repeaters used?

3. Name three types of repeaters.

4. Could the polar direct-point repeater be replaced by the single-line repeater?

5. Given a double-current differential duplex circuit, show how to convert one of the stations into a repeater station.

6. Is marking or spacing bias cumulative where single-line and polar direct-point repeaters are used?

7. What advantage does the regenerative repeater have over other types?

SECTION IX

TELEGRAPH SWITCHBOARDS

66. Requirements of telegraph switchboards.—Telegraph switchboards are very similar in many respects to telephone switchboards. Some of their requirements are as follows:

a. Line connections.—The primary need for switchboards is to connect two or more line circuits together in any combination desired. For telegraph switchboards this requires that lines of both ground return and metallic return circuits may be connected together through the switchboard.

b. Communication with stations.—It is, of course, also necessary that provisions exist for communicating with the stations so that they may give the operator necessary instructions as to the connections desired.

c. Signaling.—Means are provided for the stations to signal the operator and for the operator to signal the stations.

d. Supervision.—It is necessary that there be some means for the stations to let the operator know when a connection is no longer desired, so some means of supervision is used.

e. Expansion.—Most telephone switchboards have some means provided for connecting two or more boards in multiple, for increasing the number of lines that may be handled. The same is true for telegraph switchboards.

f. Constant line current.—The current in a telegraph line should remain constant regardless of which or how many circuits are connected to it.

g. Repeaters.—Telegraph switchboards should contain repeaters so that if two stations, each of which is near its maximum working distance from the switchboard, are connected together through

the switchboard they may be able to communicate with each other. Repeaters also solve the problem of maintaining constant line current and making connections between grounded and metallic lines.

h. Distortion correction.—It is desirable, though not always possible, to prevent distortion, occurring in one line, from affecting the signals in another line when the two are connected together. The use of repeaters tends to partially reduce this transfer of distortion.

i. Adjustment of relays.—Since each circuit will terminate in relays at the switchboard, and since the adjustment of these relays depend to a large extent upon variable line conditions, it is of great benefit, though not essential, that there be provided some means of readily checking the adjustment of these relays. This method should be simple and positive. Most switchboards have some means of testing the relay while in the circuit as well as employing interchangeable plug-in type relays.

67. Neutral system switchboard.—The repeaters used in telegraph switchboards are of such type that each circuit is terminated in a half repeater. Essentially each half repeater consists of a sending relay and a receiving relay. The winding of the receiving relay and the contacts of the sending relay are connected in series in the line. When two lines are connected together at the switchboard the contacts of the receiving relay of one line are connected to control the operation of the sending relay in the other line.

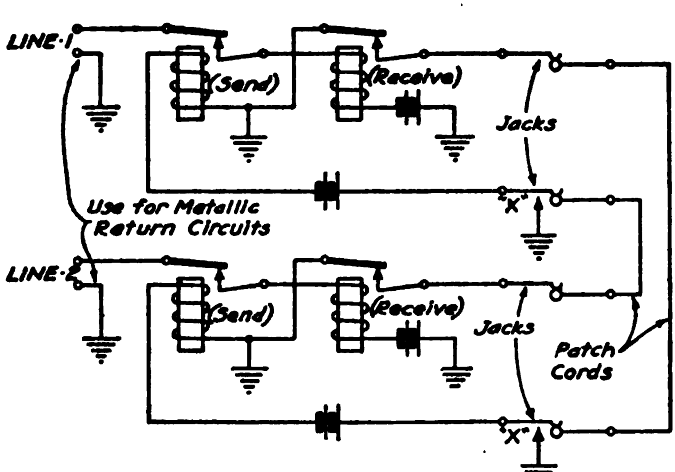


FIGURE 52.—Basic circuit of telegraph switchboard.

a. Basic circuit.—Figure 52 shows the basic circuit used in telegraph switchboards. It can be seen from this circuit that the release of the receiving relay in line *1*, as a result of incoming impulses, controls the operation of the sending relay in line *2* and the contacts of this sending relay transmit the impulses on to line *2*. The use of the simple neutral type relays in this circuit, however, presents another problem. Upon study of figure 52 it can be seen that if the receiving relay of line *1* is released and, as a result, the sending relay of line *2*; then the opening of the contacts of this sending relay will cause the receiving relay of line *2* to release, opening the circuit of the sending relay of line *1*, and both circuits will then be locked open. Some method must be used to prevent the release of a receiving relay as a result of the sending relay in the same line circuit being released.

b. Make-before-break relay.—A solution to the problem has been found in the use of the make-before-break type relay. This relay has an additional contact as shown in figure 53. The relay armature closes with a make contact which is somewhat flexible and as the armature continues in its movement the make contact is pulled away from the break contact. Thus, when released as in

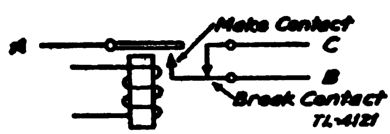


FIGURE 53.—Make-before-break relay.

figure 53 the circuit is closed from *B* to *C*, but as the relay is operated the circuit is first closed from *A* to *B* and then opened between *B* and *C*.

68. Basic circuit with make-before-break relay.—Figure 54 shows the basic circuit of the telegraph switchboard employing a make-before-break relay as the sending relay. All relays are shown in the normal or operated position. If a spacing impulse is transmitted from line *1* the receiving relay of that line circuit will release. The circuit from ground through the receiving relay contact of line *1*, the patch cord, battery, sending relay of line *2* and back to ground will now be opened. This causes the sending relay of line *2* to release, transmitting the space impulse to line *2*. Opening the sending relay contacts of line *2* does not release the receiving

relay of line 2 because of the holding circuit completed through the make-before-break contact arrangement. When there are no patch cords connected into a line circuit the sending relay is held operated by a grounded contact in the jack at point *X* in figures 52 and 54.

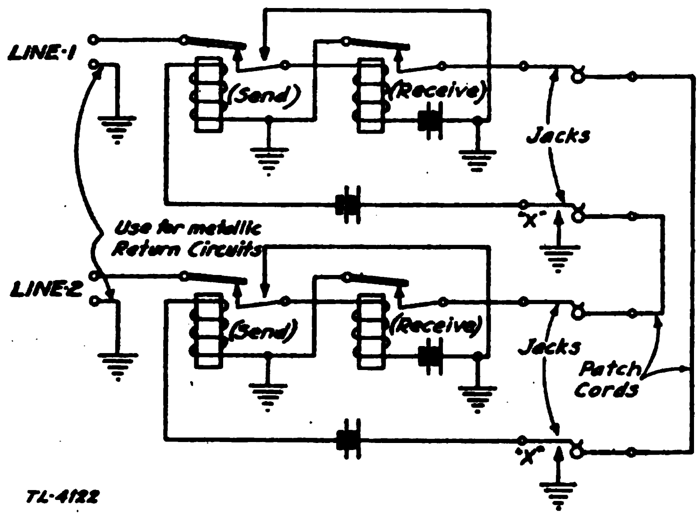


FIGURE 54.—Basic circuit of telegraph switchboard with make-before-break relay.

a. Signaling.—Signaling may be accomplished through any one of several methods. One of the most common is the use of additional contacts on the receiving relay which controls the action of a slow acting relay. If the line circuit is held open (by use of the break key on the teletypewriter) for a long period as compared to the open period occuring during the transmission of signals, the slow acting relay will release, closing a circuit for a signal lamp. The normal opening and closing of the receiving relay contacts during transmission is too fast to permit the slow acting relay to release and no lamp signal is received unless the break key is held depressed for at least a second or two.

b. Supervision.—Supervision by the operator may be obtained either by separate supervisory signals as in commercial switchboards, or by use of the line signals as in the army switchboard BD-100. Generally in a neutral system when the connection is no longer desired the station originating the call should recall the operator to notify him that the connection may be taken down.

This method of supervision is similar to that employed by the local-battery magneto telephone system. If the operator's circuit is terminated in a manner similar to that of a line circuit the operator may be connected to any circuit by means of patch cords or key arrangements. Line circuits appear in two jacks with patching being completed from the top jack of one circuit to the lower jack of the other circuit. In this manner conference connections, where several circuits are connected together at one time, are possible. Since each circuit is individually terminated, patching connections may be made between line circuits connected to separate switchboards when these switchboards are located together. This provides for expansion of an office. For the same reason line currents will not be affected by patching so that connections may be made between line circuits of stations which would otherwise be too far apart for communication.

c. *Adjustments.*—The line circuits usually include a rheostat for varying the line current and a key arrangement for connecting a milliammeter into the line to measure the line current. The tension on the relay springs should be adjusted so that as the relay receives a given signal its contacts will transmit it on with the proper time intervals. The contacts should be closed and opened in accordance with the signal to be transmited. If the tension is too great the contacts will tend to stay open longer than they should, and likewise if the tension is too light they will be slow in releasing and stay closed too long. A special test circuit is often provided for testing the relay contacts. This test circuit is referred to as a bias testing or relay test circuit.

69. Relay test circuit.—Vibrating relay contacts may be considered as having an effective resistance over a period of time. When the contacts are closed their resistance is zero and when open it is infinite. Over a period of time it may be considered that they have a resistance which depends upon the resistance of the circuit in series with the contacts and the proportion of time when the contacts are closed. If the resistance of the circuit in series with the contacts is 1500 ohms it will be found, for example, that the effective resistance of the contacts transmitting a continuous space bar signal, as shown in figure 31, will be 3115 ohms. As stated before, this value will vary with the value of resistance in series with the contacts and is given merely as an example. The relay test circuit, figure 55, consists of a Wheatstone bridge employing

the effective resistance of the relay contacts as one arm of the bridge. In making the adjustments the signals must be transmitted continuously while the spring tension is being changed. With teletypewriters the signal which can be transmitted most conveniently

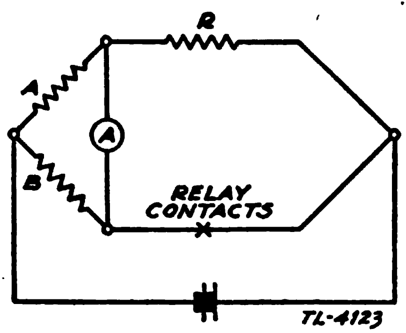


FIGURE 55.—Relay test circuit.

for this test is that which is transmitted when the space bar of the teletypewriter is held down. For this reason the bridge is designed so that it will be balanced when the relay contacts present an effective resistance equal to that corresponding to the continuous space bar signal. The relay contacts are then connected into the test circuit, the space bar of the teletypewriter is held down and the spring tension is adjusted until the bridge is balanced. In testing the receiving relay contacts the distant station will transmit the space bar signals, and in testing the sending relay the transmissions must be toward the distant station.

70. Questions for self-examination.—

1. What features are desired in telegraph switchboards?
2. Explain the operation of a make-before-break relay.
3. Draw the basic circuit with make-before-break relays and explain its operation in terminating a line at a telegraph switchboard.
4. How may conference connections be obtained in a telegraph switchboard?
5. What types of adjustments are necessary in telegraph switchboards?
6. Explain the operation of the relay test circuit.

APPENDIX I

INDEX TO TECHNICAL AND FIELD MANUALS

(See FM 21-6 for complete list)

TM 11-302	Charging Set SCR-169
TM 11-330	Switchboards BD-71 and BD-72
TM 11-331	Switchboard BD-14
TM 11-332	Telephone Central Office Set TC-4
TM 11-333	Signal Corps Telephone EE-8-A
TM 11-335	Telephone Central Office Set TC-1
TM 11-340	Telephone Central Office Set TC-2
TM 11-345	Cabinet BE-70-( ), Wire Chief's Testing Cabinet
TM 11-351	Telegraph Sets TG-5 and TG-5-A
TM 11-353	Installation and Maintenance of Telegraph Printer Equipment
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FM 1-45	Signal Communication; Air Corps
FM 5-10	Communication, Construction, and Utilities; Engineer
FM 11-5	Missions, Functions, and Signal Communication in General; Signal Corps
FM 24-5	Signal Communication

APPENDIX II

GLOSSARY OF TERMS

The following definition of words and terms apply only to their usage in this text.

Alternating current —Current that periodically reverses in direction.

Alternator.—An a-c generator.

Ammeter.—A current meter with a scale calibrated in amperes.

Ampere.—Unit of flow of electrical current; i.e. that amount of current which will flow through a resistance of one ohm when a potential of one volt is applied.

Armature.—The rotating assembly of a d-c motor or generator; also the movable iron part which completes the magnetic circuit in certain apparatus.

Battery.—A device for converting chemical energy into electrical energy; one or more cells.

Bias.—*Line bias.*—The effect on the length of telegraph signals produced by the electrical characteristics of the line and equipment. If the received signal is longer than that sent, the distortion is called marking bias; if the received signal is shorter, it is called spacing bias.

Applied bias.—A force (electrical, mechanical, or magnetic) exerted on a relay or other device which tends to hold the device in a given electrical or mechanical condition.

Bias distortion.—The distortion produced by bias.

Break contact.—That contact of a switching device which opens a circuit upon the operation of the device.

Break key.—On a teletypewriter the key used to break into the transmission being received from another station.

Bridge.—A shunt path; a device used in the electrical measurement of impedance, resistance, etc.

Bypass.—A shunt path around some element or elements of a circuit.

Capacitance.—The ability or capacity to receive an electrical charge.

Capacitor.—A device for inserting the property of capacitance into a circuit; two or more conductors separated by a dielectric.

Cell.—A combination of electrodes and electrolyte which converts chemical energy into electrical energy.

Characteristic.—A distinguishing trait, quality, or property.

Circuit.—A closed path or mesh of closed paths which may include a source of emf.

Closed-circuit System.—A telegraph system in which, when no station is transmitting, the circuit is closed and current is flowing in the circuit.

Composite.—A method of simultaneously operating telephone and d-c telegraph circuits over the same conductors in which one telegraph circuit may be obtained on each conductor.

Condenser.—Same as capacitor.

Continuity.—A condition of a circuit where a closed electrical path is obtained.

Cross.—A type of line trouble in which one circuit becomes connected to one or more other circuits.

Crossfire.—A condition where telegraph signals on one circuit cause interference in other telegraph or telephone circuits.

Current.—A flow of electrons in a circuit.

Direct current.—Current which is constant in direction.

Differential.—Pertaining to, or involving, a difference; i.e., a differential current device is one which operated upon the basis of a difference in two current values.

Distortion.—An alteration or deformity of a wave form.

Duplex.—Operation in two directions simultaneously over one circuit.

Electrode.—The solid conductors of a cell or battery which are placed in contact with the electrolyte; a conductor which makes electrical contact with a liquid, gas, or an electron cloud.

Electrolyte.—A solution in which, when traversed by an electric current, there is a liberation of matter at the electrodes, either an evolution of gas or a deposit of a solid. Usually refers to the solution in a battery.

Electromagnet.—A core of magnetic material, such as soft iron, which is temporarily magnetized by passing an electric current through a coil of wire surrounding it, but loses its magnetism as soon as the current stops.

Electromotive force.—*emf.*—Difference of electrical potential o pressure measured in volts.

Electrons.—One of the negative particles of an atom.

Energy.—That capacity for doing work.

Field of force.—Region in space within which a force is effectiv

Flux.—The magnetic lines of force.

Force.—That which tends to change the state of rest or motion o matter.

Function.—The duty or job performed by a device; with regard to teletypewriters, the mechanical operation of line feed, carriage return, letters shift, figures, unshift and space.

Fuse.—A circuit protecting device which makes use of a substance which has a low melting point.

Generator.—A device for converting mechanical energy into electrical energy.

Ground.—The contact of a conductor with the earth; also the earth when employed as a return conductor.

Holding coil.—A separate coil of a relay which is energized by the operation of the relay and holds the relay operated after the original operating circuit is deenergized.

Howler.—An electromechanical device for the production of an audio-frequency tone.

Impedance.—The total opposition to the flow of current consisting of resistance and reactance.

Inductance.—Property of a circuit which opposes a change in current.

Inductive reactance.—The opposition to the flow of alternating or pulsating current due to the inductance of the circuit.

Insulator.—A medium which will not conduct electricity.

Jack.—In combination with a plug, a device by which connections can readily be effected in electrical circuits.

Key.—A hand operated device for the rapid opening and closing of a circuit or circuits.

Keyboard perforator.—A mechanism consisting of a keyboard and a perforator by which means a tape is perforated in accordance with a code corresponding to the depressed character key of the keyboard.

Leakage.—Term used to express current loss through imperfect insulation.

Lines of force.—A path through space along which a field of force acts. (Shown by a line on a sketch.)

Magnetic pole.—Region where the majority of magnetic lines of force leave or enter a magnet.

Magnetomotive force.—The force which is necessary to establish flux in a magnetic circuit or to magnetize an unmagnetized specimen.

Make contact.—That contact of a device which closes a circuit upon the operation of the device.

Margin.—The upper and lower limits through which the index arm of the range finder mechanism of a teletypewriter may be moved and still receive correct copy.

Marking bias.—That bias which affects the results in the same direction as marking current.

Marking contact.—That contact of a telegraph relay which is closed when marking current is controlling the relay operation.

Marking current.—That magnitude and polarity of current in the line when the receiving mechanism is in the operated position.

Microfarad.—Practical unit of capacitance; one-millionth of a farad.

Milliampere.—Unit of electric current; equal to one-thousandth of an ampere.

Milliammeter.—Current meter with a scale calibrated in milliamperes.

Multiple.—Parallel connection whereby any number of identical pieces of equipment may be connected into the circuit.

Network.—An electrical circuit made up of series or shunt impedance or combinations of series and shunt impedances.

Ohm.—Fundamental unit of resistance.

Ohmmeter.—A direct reading instrument for measuring resistance, calibrated in ohms.

Open-circuit system.—A telegraph system which, when no station is transmitting, no battery is in the circuit and no current is flowing.

Parallel circuit.—A circuit in which one side of all component parts are connected together to one line while the other side of all components are connected together to another line.

Patching.—The temporary connection of the two lines or circuits together through other than the use of regular switchboard cord circuits.

Patching cord.—A cord terminated on each end with a plug, used in patching between circuits terminated in jacks.

Permanent magnet.—A piece of steel or alloy which has its molecules lined up such that a magnetic field exists without the application of a magnetomotive force.

Phantom circuit.—A telephone circuit which is superimposed upon two other circuits such that the two conductors of one circuit act combined as one conductor for the phantom circuit and the conductors of the second circuit act as the other phantom conductor.

Plug.—In combination with a jack, a device by which connections can readily be effected in electrical circuits.

Polar.—A system of telegraphy in which the current in the line is reversed in polarity in changing from marking to spacing.

Polarential.—A telegraph transmission system in which transmission in one direction is polar with equal and opposite transmitting voltages for marking and spacing, and transmission in the other direction is differential with voltage applied for the spacing condition and ground for the marking condition.

Potential difference.—The degree of electrical pressure exerted by a point in an electrical field or circuit in reference to some other point; same as electromotive force or voltage.

Prolongation.—That interval of time between the opening of the circuit and the release of the receiving mechanism.

Protector.—A device to protect equipment or personnel from high voltages or currents.

Pulsating current.—Current of varying magnitude but constant direction.

Rectifier.—A device for charging alternating current to pulsating current.

Relay.—A device for controlling electrical circuits from a remote position; magnetic switch.

Repeater.—A device for the retransmission of a signal, usually with amplification.

Repeating coil.—An audio-frequency transformer for transferring energy from one electrical circuit to another, usually one-to-one ratio with one side (line connection) arranged so that a center tap may be obtained for simplexing.

Reperforator.—A device for the reception of teletypewriter signals as electrical impulses from a line and converting them into perforations in a tape.

Resistance.—The opposition offered by a conductor to the passage of either direct or alternating current. That portion of impedance which causes power loss.

Retardation.—The interval of time between the closing of the circuit and the operation of the receiving mechanism.

Rheostat.—A variable resistance for limiting the currents in a circuit.

Rotor.—The rotating part of an electrical device.

Self inductance.—Inductance associated with but one circuit.

Series circuit.—An electrical circuit in which the component parts are placed end-to-end and form a single continuous conductor; opposite of parallel.

Short.—A type of line trouble in which the two conductors of a pair become connected together.

Shunt.—A parallel or alternate path for the current in a circuit; usually with some impedance other than zero; not used with reference to trouble. (See Short.)

Simplex.—A method of obtaining a telegraph channel by use of repeating coils or bridged impedances.

Sounder.—A receiving instrument used in telegraphy to produce audible signals by means of an armature operated between two stops.

Spacing bias.—That bias which affects the results in the same direction as spacing current.

Spacing contact.—That contact of a telegraph relay which is closed when spacing current is controlling the relay operation.

Spacing current.—That magnitude and polarity of current in the line when the receiving mechanism is in the unoperated or released position.

Stator.—That part of an electrical device which remains stationary when in use.

Subscriber.—A person or organization to whom service is extended.

Supervision.—The process of watching over the condition of a connection at a switchboard to determine when subscribers are through using the connection.

Switch.—A device for opening, closing, or rerouting an electrical circuit.

Switchboard.—A board containing apparatus for controlling or connecting electrical circuits.

Synchronism.—The state of being synchronous.

Synchronous.—Having the same period and phase; happening at the same time.

Telegraphy.—A means of communication whereby a message is transmitted a character at a time employing a code of impulses of various lengths and combinations to designate the individual characters.

Teletypewriter.—An electromechanical device for the transmission of characters as electrical impulses, the analysis, and printing of the characters corresponding to the impulses received.

Terminal.—One end of an electrical circuit.

Transmission.—The passing of energy through a conductor.

Transmitter-distributor.—A distributor consisting of a rotating arm with brushes in contact with conducting segments of a circle, used in the transmission of teletypewriter signals.

T.W.X.—A trunk between teletypewriter central offices; in the Army, referred to trunks from Army teletypewriter switchboards to commercial switchboards.

Volt.—Unit of potential, potential difference, emf, or electrical pressure.

Voltmeter.—An instrument for measuring potential difference or electrical pressure, calibrated in volts.

Working margin.—The difference in current through the line relay of the receiving telegraph station when the key of the sending telegraph station is open and when it is closed.

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BY ORDER OF THE SECRETARY OF WAR:

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The Adjutant General.

TM 11–457

WAR DEPARTMENT

TECHNICAL MANUAL

LOCAL-BATTERY TELEPHONE EQUIPMENT

September 3, 1942

TECHNICAL MANUAL No. 11-457

WAR DEPARTMENT, WASHINGTON, September 3, 1942.

LOCAL-BATTERY TELEPHONE EQUIPMENT

SECTION I

GENERAL

1. **Purpose.**—The purpose of this text is to acquaint the student with basic fundamentals governing local battery telephony.

2. **Scope.**—The general application of various circuits and combination of circuits used in wire telephony is discussed in this text. On the other hand, no attempt is made to cover special application of the various circuits in specific equipment, because all such equipment and circuits employed are covered adequately in various technical manuals issued by the Signal Corps.

3. **Advantages of telephony.**—Telephony has certain advantages over telegraphy in that the spoken word can transmit more intelligence than the printed word, and the subject of the message can be discussed directly by the parties concerned without the formality of exchanging messages, and specially trained operators are not required for transmission and reception. Wire telephony, when available, also has certain advantages over radio telephony in that it is usually secret, it is not affected by static, and operation is not so critical.

4. **Use of telephony.**—Due to the reliability and ruggedness of the telephone equipment, telephone communication is used from the lowest unit in the field up to the highest. Since the members of a command are, as a rule, used to using the telephone as the primary means of communication, it becomes necessary, quite frequently, to re-educate them so that all of the means of communication will be used to their fullest capacity and greatest efficiency.

SECTION II

THE LOCAL-BATTERY TELEPHONE

5. **The components of the local-battery telephone.**—The seven components of the local-battery telephone are the receiver, the transmitter, the battery, the induction coil, the hook switch, the hand generator and the ringer. Each of these parts will be described in detail, and the local-battery telephone circuit will be built up in steps from the simplest circuit to the final completed form.

6. **The receiver.**—*a*. The mechanical construction of a telephone receiver is shown in figure 1. The receiver contains a U-shaped permanent magnet which holds the diaphragm under a constant pull. The current at voice frequency passes through the coils which are wound around the pole pieces attached to the ends of the permanent

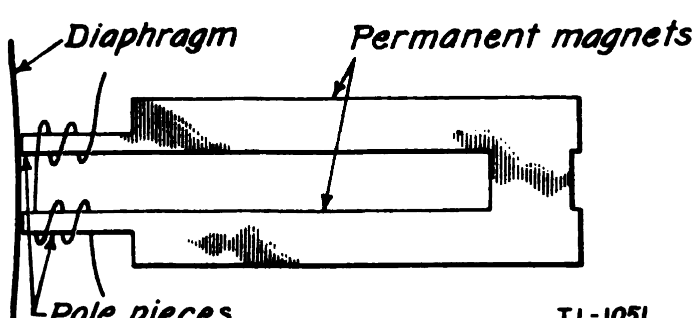

FIGURE 1.—Schematic diagram of a telephone receiver.

magnet. The magnetic field produced by the voice currents alternately aids and opposes the field of the permanent magnet. Thus the pull on the diaphragm alternately increases and decreases, causing the diaphragm to vibrate in synchronism with the voice frequency current through the windings of the coils. The vibration of the diaphragm produces the sound waves.

b. All modern receivers are equipped with permanent magnets and it is important that this magnetism not be destroyed by jarring or other abuse. It is evident that a direct current could be put through the windings of the coils in such a direction as to destroy or impair the permanent magnet. The permanent magnet holds the diaphragm taut, making the receiver more sensitive. It also prevents the diaphragm from vibrating at twice the applied frequency.

c. Some of the troubles encountered in receivers are as follows: (a) bent diaphragm, (b) rust or dirt on pole pieces preventing motion of diaphragm, (c) incorrect clearance or gap between diaphragm and pole pieces, causing receiver to rattle on strong impulses, (d) loose diaphragm, (e) open winding, (f) open receiver cord.

d. Figure 2 is a cross-sectional view of the HA 1 receiver unit which is the present standard in the Bell System. This receiver which is of the bipolar permanent magnet type employs in its con-

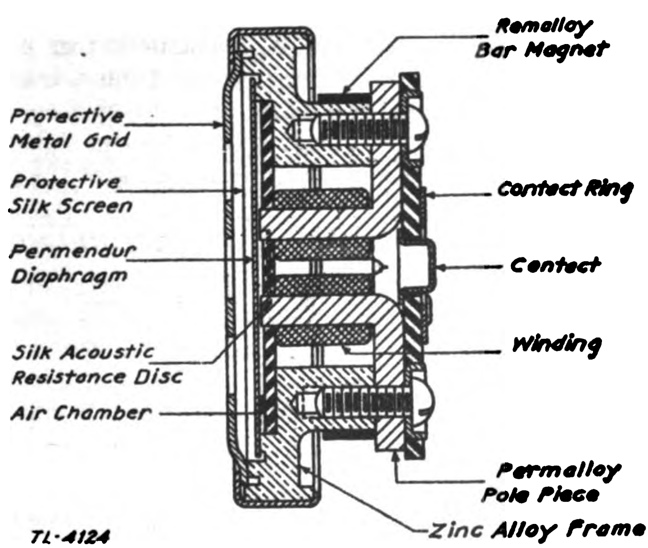

FIGURE 2.—Cross-section of a standard receiver unit.

struction three comparatively new magnetic alloys with special magnetic characteristics. It is substantially more efficient than any previous design. It also differs notably from earlier types in the extent to which the motion of the diaphragm, which is made of vanadium-permendur, is affected by "acoustic controls." One acoustic control is directly behind the diaphragm, and the other is enclosed between the diaphragm and the inner surface of the receiver cup when the receiver unit is mounted in the telephone instrument. The former control consists of an air chamber with an outlet to the back of the receiver unit through a small hole covered with a silk disc. The latter consists of an air chamber which opens into the air through six holes in the receiver cap. These air chambers are designed to have "acoustic impedances" which match the "electrical impedances" of the receiver and improve its overall efficiency appreciably. The diaphragm, which is unclamped, rests on a ring-shaped ridge and is held in place by the pull of the magnet. By this method variations in receiver efficiency at different frequencies are practically eliminated within the voice range. The two permalloy pole pieces are welded to a pair of strong remalloy or cobalt-steel bar magnets, and the assembly is fastened to a zinc alloy frame. The whole unit is held together by a brass ferrule on the back of which are mounted two silver plated contacts for the electrical connections. Under no circumstances should direct current be passed through this type of receiver. Due to the small cross-sectional area and high concentration of magnetic flux in the magnets even a momentary flow of direct current may cause them to lose a large amount of their magnetism.

e. The original telephone as invented by Bell in 1876 consisted of a receiver which was used both as a transmitter and a receiver. The simplest form of telephone circuit, therefore, consists of two receivers connected by a pair of wires. The voice waves of the speaker cause the diaphragm to vibrate. This vibration changes the air gap of the magnetic circuit, thus varying the magnetic flux through the coils, and as a result, a voltage is induced in the coil windings. As the circuit is complete, talking current flows and operates the other receiver. It is easily seen that this current would be small and that this circuit is of little practical use except in cases of emergency.

7. The transmitter.—*a*. Although the principle of Bell's original telephone applies to the present day telephone receiver, it was ap-

preciated in the early stages of telephone development that the electrical energy generated by a diaphragm vibrating in a magnetic field was insufficient for the transmission of speech over any considerable distance. The maximum energy available for such an instrument would be limited to the energy contained in the voice waves striking the diaphragm. One year after the invention of the original telephone, the Blake transmitter was introduced. It worked on the principle of a diaphragm varying the strength of an already established electrical current, instead of generating electrical energy by means of electromagnetic induction. By this method a large amount of electrical energy is controlled by the small amount of energy contained in the sound waves. Since the transmitter does not generate the electrical energy, an external source must be provided. This source, in practically all cases, is a battery.

b. The principle of the transmitter is that the contact resistance of carbon varies with the pressure of the contact. In nearly all modern transmitters carbon is used in the form of fine granules. These granules are contained in a cup, and the pressure is varied by means of a plunger or piston acting within the cup and mechanically connected to the diaphragm. The cup and piston with the granules is known as the transmitter button. Figure 3 is a schematic drawing of a transmitter which will give an idea of the electrical path through the transmitter and how the resistance of the path is varied.

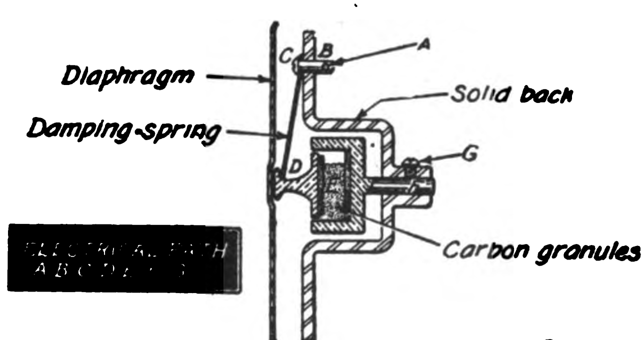

FIGURE 3.—Schematic diagram of a positional telephone transmitter.

c. Figure 4 shows in cross-section the nonpositional transmitter unit which is present standard for subscriber telephone sets. This transmitter is of the "direct action" type; that is, the movable element attached to the diaphragm, which actuates the granular

carbon, is an electrode, and serves the dual purpose of contact and pressure surface. As the drawing shows this dome-shaped electrode is attached to the center of a conical diaphragm, and forms the front center surface of the bell-shaped carbon chamber.

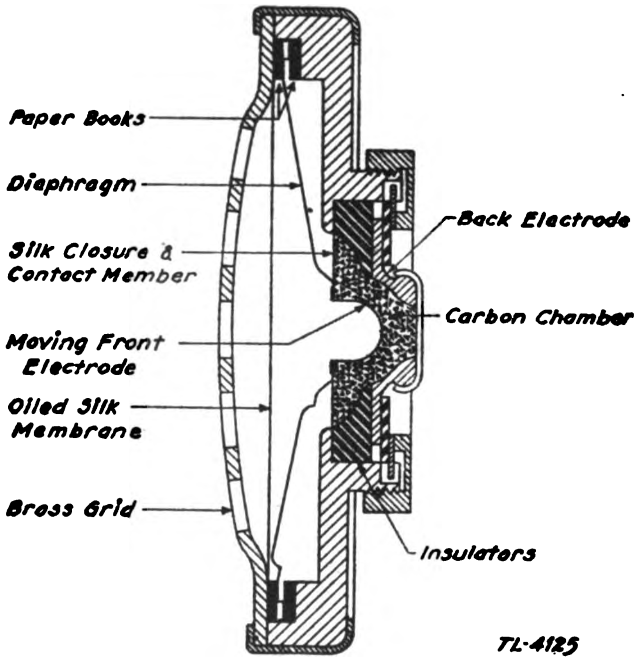

FIGURE 4.—Cross-section of a standard nonpositional transmitter unit.

d. The diaphragm is made of aluminum alloy 0.003 inch thick with radial ridges to increase stiffness. Paper "books," which consist of a number of thin impregnated paper rings, support the diaphragm at its edge on both sides. The carbon chamber is closed on the front side by a silk membrane clamped under the diaphragm electrode. A light spoked copper contact member, clamped under the diaphragm electrode, is the means of providing a flexible connection between this front electrode and the supporting metal frame. The fixed back electrode is held in place in a frame by a threaded ring and is insulated by a phenol fibre washer and a ceramic insulator which also forms one of the surfaces of the carbon chamber. The active surfaces of both electrodes are gold plated. A brass plate which is perforated with large holes protects the vibrating part against mechanical injury. Moisture is kept out of

the working parts by an oil silk moisture-resisting membrane placed between the brass plate and the diaphragm. The shape of the electrodes and the carbon chamber provides sufficient contact force betwen the diaphragm electrode and the granular carbon in the zone of maximum current density so that this transmitter operates satisfactorily in any position. When new it has a resistance of around 30-40 ohms.

e. Transmitters made by various manufacturers may differ in constructional details but all of them work on the same fundamental principle.

f. Transmitter troubles can be classified as packing, heating, rattling and resonating. The last is a fault of design or construction and is rarely encountered. Rattling is caused by a loose diaphragm or loose contact within the transmitter unit. Heating is caused by passing too great a current through the transmitter causing pitting of the granules and giving rise to packing. Broken granules, the presence of dust and dampness also lead to packing. In a packed transmitter the granules are stuck together and vibrations of the diaphragm cannot vary the contact resistance.

g. The nonpositional transmitter may be used in any position, but the older types of transmitters must be held with the diaphragm vertical or nearly so. If it is held horizontal the carbon granules will fall away from one of the contacts and open the circuit. It should always be remembered that a transmitter will never generate a voltage, but is merely a variable resistor that can be used to control a flow of current from some other source.

h. The use of the transmitter greatly improved the simple telephone circuit as conceived by Bell. Figure 5 shows a diagram of a talking circuit using a transmitter, receiver, and battery at each station. This arrangement has two defects which must be overcome before it is of practical use: (1) it would require high battery voltage, especially on long lines, (2) the change in resistance of the

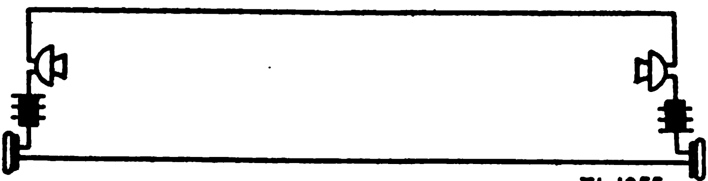

FIGURE 5.—Simple series telephone circuit.

circuit which can be caused by talking into either transmitter is extremely small compared to the circuit resistance; hence the percentage change in current will be correspondingly small. To overcome these defects, induction coils are used at each station.

8. The local-battery induction coil.—A telephone induction coil is a transformer which is efficient over a wide range of voice frequencies. Figure 6 shows the fundamental talking circuit using induction coils. It should be noted that, with this arrangement, the resistance of the local transmitter circuit is relatively low, in fact, practically all of its resistance is that of the transmitter. The results are (1) a large current flows through the transmitter when a

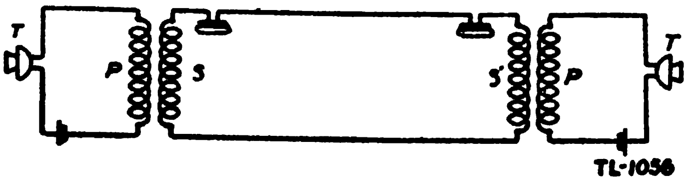

FIGURE 6.—Local-battery telephone circuit with induction coil.

comparatively low battery voltage (usually 3-6 volts) is applied, (2) a given resistance change in the transmitter causes a large percentage change in the current flow. A common type of induction coil used in local-battery telephony is the W. E. No. 13. The resistance of the primary of this coil is 1.8 ohms and the secondary resistance is 22 ohms. There are 400 turns in the primary and 1700 in the secondary; thus, it is a step up transformer of approximately 1 to 4 ratio. This gives an additional improvement in transmission by increasing the voltage and reducing the current in the secondary for a certain power transfer.

9. The hook switch.—*a.* The telephone circuit now set up has two definite disadvantages. There is no easy way to open the primary circuit and the battery would soon be exhausted. The secondary circuit is also continually across the line. This will not cause trouble in figure 6 but when the signaling circuit has been added it will shunt out the ringer and the bells will not ring. A solution of these two defects calls for a device that will open these two circuits when the telephone is not in use and close them when it is in use. The closing and opening of the primary and secondary circuits are accomplished by the hook switch, which is a spring return switch

that breaks the two circuits when the weight of the receiver is on the hook. One form of this switch is shown in figure 7. It provides a place for hanging the receiver when the latter is not in use.

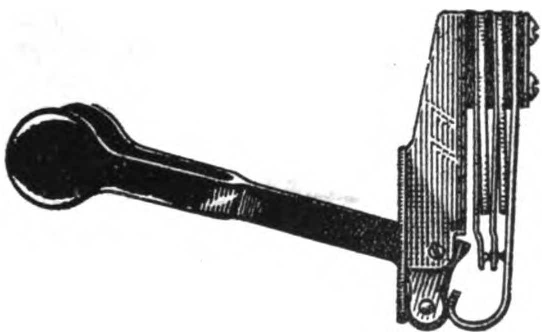

FIGURE 7.—A telephone hook switch.

b. The hook switch is usually connected into the circuit as shown in figure 8. Insofar as transmitting and receiving are concerned the telephone circuit is complete, but a method is needed to signal the party at the distant end of the line when he is wanted on the line and to allow him to call the local party to the telephone.

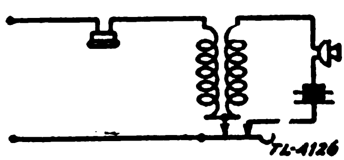

FIGURE 8.—Primary and secondary circuits of a local-battery telephone.

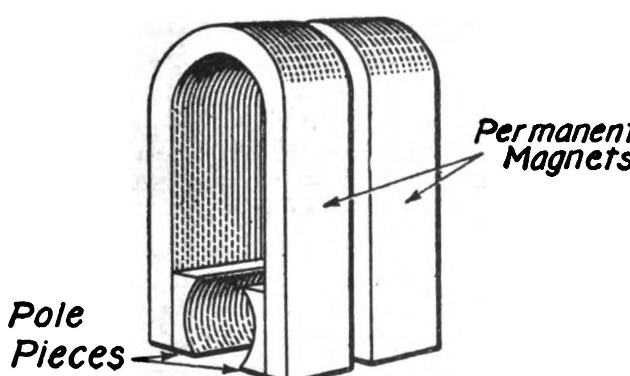

FIGURE 9.—Magneto generator magnets and pole pieces.

10. The hand generator or magneto.—*a.* The field of a typical hand generator consists of from two to five U-shaped steel permanent magnets arranged with like poles on the same side. These magnets are provided with cast iron pole pieces. This gives the arrangement shown in figure 9. A strong field exists between these pole pieces. End plates with bearings are secured across the ends of the pole pieces and in these bearings an armature is mounted. Figure 10 shows two views of an armature.

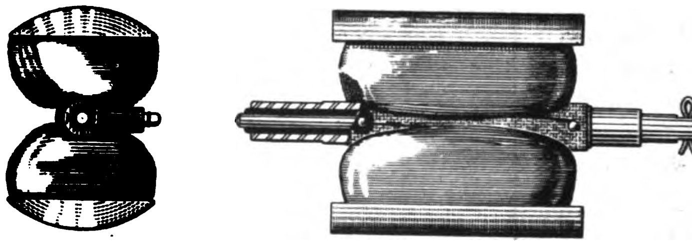

FIGURE 10.—Magneto generator armature.

b. The fewer the bars in the permanent magnet, the greater must be the number of turns in the armature winding, ranging from about 3000 for a 3-bar generator to about 1700 for a 5-bar machine. On one type of generator, one terminal of the winding is grounded to the armature core and the other is connected to a pin set into the axis of the shaft and insulated from the remainder of the shaft. Contact made with this pin by a flat spring gives one terminal of the generator, while connection to the generator frame gives the

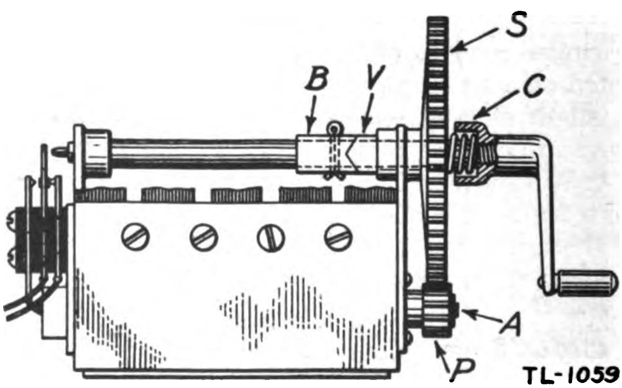

FIGURE 11.—Magneto generator assembly without permanent magnets.

other. Other types of magnetos have slightly different arrangements. Figure 11 shows the gear and crank arrangements for driving the magneto.

c. The crank turns a shaft extending all the way through the generator. Over this shaft is mounted a pointed sleeve *V* and to this sleeve is secured a large gear *S*. Pinned to the shaft is another sleeve *B* so notched as to engage the points of the sleeve *V*. A spring coiled about the shaft presses against the larger gear wheel and the collar *C* which is integral with the shaft; and this spring forces *B* to engage with *V*. As the crank is turned, the magnetic field tends to prevent the armature from turning, and this drag, through the gears, holds sleeve *V*. Rotation of the crank then causes the inclined face of *B* to ride up the face of *V* until the collar *C* jams against the hub of the gear *S*, which prevents further longitudinal movement of the shaft and causes the armature to rotate. The principal reason for this action is to cause the shaft to move endwise and operate a switch. This switch is of the break-one, make-one type. The make contact places the generator across the line and the break contact may remove the ringer from across the line as will be seen later. The pinion *P* is usually so connected to the shaft *A* that when cranking has ceased, the armature is free to rotate and aline itself with the field between the pole pieces. This lengthens the life of the permanent magnets. A magneto turned at normal speed will develop an electromotive force of about 85-90 volts at a frequency of 17-20 cycles.

11. The telephone ringer.—*a.* Figure 12 illustrates the ringer used in telephone instruments. This device operates on the 20-cycle alternating current put out by the hand generator.

b. The ringer consists of two electromagnets M_1 and M_2 which are mounted on a soft iron yoke *Y*. The armature is pivoted so as to give a slight air gap separation between its two ends and the cores of the respective magnets. The tapper rod *R* is securely fastened to the armature. One end of the permanent steel magnet *S* is mounted near the middle of *Y* and the other end is near the center of the armature. The two gongs G_1 and G_2 are mounted so that the tapper strikes first one and then the other as it vibrates between them.

c. The theory of the ringer can be better understood by referring to figure 13. In figure 13, *N* represents the north pole of the permanent magnet and is mounted very close to the center of the

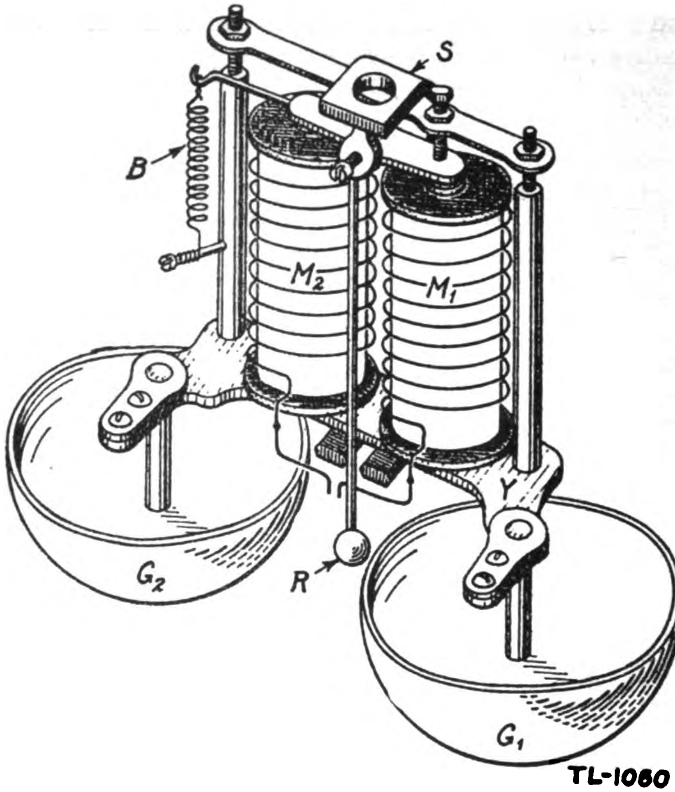

FIGURE 12.—Ringer assembly.

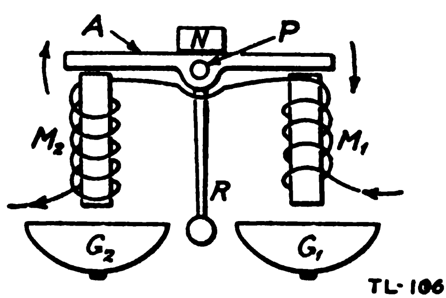

FIGURE 13.—Schematic diagram of a ringer.

soft iron armature *A*. This induces an *S* pole at the center and an *N* pole at each end of the armature. Let us assume that 20-cycle ringing current is passing through the windings and that its direction during the present half cycle is as shown. This makes the

upper end of M_1 an S pole and the upper end of M_2 an N pole. Thus the armature will rotate in the direction indicated about its pivot P, and the tapper will strike G_2. During the next half cycle the direction of current is reversed, so is the direction of armature rotation, and the tapper will strike G_1. Ringers of this kind having permanent magnets are called polarized ringers. They have resistances of from 1000 to 4250 ohms. The impedance of such a ringer to voice frequency currents is approximately 30,000 ohms, so it can be seen that a ringer across the line during conversation does not cause material transmission losses.

12. **Ringing circuits.**—*a.* In the two-way ringing circuit with standard generator, the ringer and line are so connected to the generator switch that when neither generator is being turned, the generators stand open and the ringers are connected across the line as shown in figure 14. But as soon as either generator crank is turned, that generator is connected across the line and the ringer at that sta-

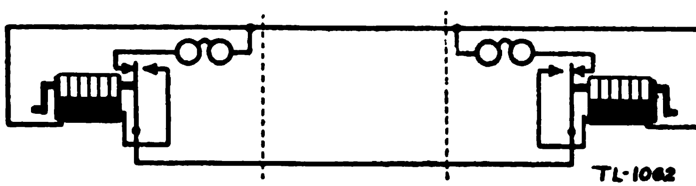

FIGURE 14.—Complete signaling circuit.

tion may or may not be disconnected from the line. Figure 15 shows a condition where the generator at *A* is being cranked and is sending current out to operate ringer at *B*. This diagram shows the ringer at *A* as having been disconnected from the line. Other hookups showing the ringer permanently across the line will be shown later. In figure 8 was shown the diagram of the talking circuit and

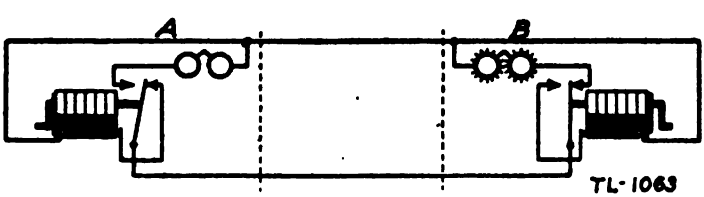

FIGURE 15.—Complete signaling circuit *A* ringing.

now in figure 15 there is shown the signaling circuit. There is no reason why the two cannot be combined, and then one pair of wires

can be used for both talking and signaling. All this requires is the addition of a hand generator and ringer to each telephone as shown in figure 8. The result is shown in figure 16.

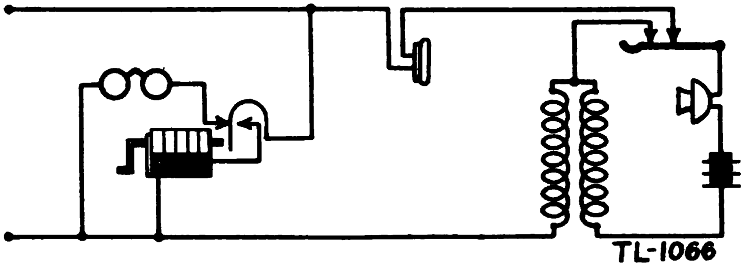

FIGURE 16.—Local-battery telephone complete.

b. The ringing circuit considered above is the Western Electric or open-out circuit. Another notable circuit is shown in figure 17.

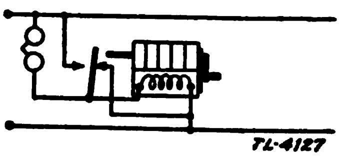

FIGURE 17.—Stromberg-Carlson or shunt-out signaling circuit.

By inspection it can be seen that the ringer and generator are shunted out when they are not supposed to operate. This circuit is known as the shunt-out or Stromberg-Carlson circuit. The same generator cannot be used for both circuits because the necessary terminals are not available.

13. The four fundamental circuits of the local-battery telephone.—These circuits are the primary, secondary, ringer and generator circuits. Figure 18 shows the primary circuit in heavy lines with the rest of telephone in light lines. The function of the primary circuit is to
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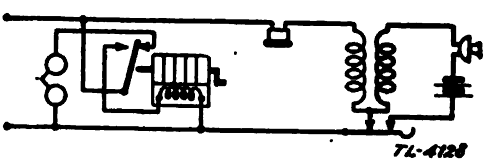

FIGURE 18.—Primary circuit of a local-battery telephone.

change sound impulses into electrical impulses and make them available to the secondary circuit. Figure 19 shows the secondary

circuit of the same telephone. This circuit has a two fold function. It must place the electrical impulses from the primary circuit on

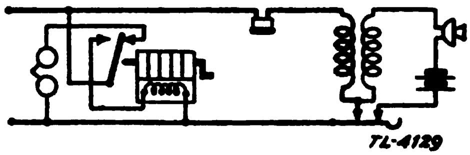

FIGURE 19.—Secondary circuit of a local-battery telephone.

the line and it must also change the incoming electrical impulses into sound impulses. The ringer circuit, as shown in figure 20, produces an audible signal when the subscriber is to be called to the telephone. When the local subscriber wishes to call the operator he

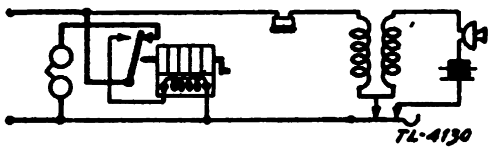

FIGURE 20.—Ringer circuit of a local-battery telephone.

must have some means of producing a strong signal at the distant end. This is accomplished by the generator circuit as shown in figure 21.

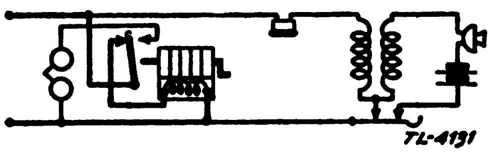

FIGURE 21.—Generator circuit of the local-battery telephone.

14. The local-battery antisidetone circuit.—*a. Definition.*—In the telephone circuits, thus far considered, the sounds picked up by a transmitter of one telephone were reproduced in the receiver of that telephone as well as in the distant receiver. This is called sidetone and becomes objectionable when the telephone is used in a noisy location. This local noise, picked up by the transmitter and reproduced by the receiver, tends to prevent the user from hearing the distant station. A circuit is used in modern telephones which substantially reduces this sidetone. This is known as the antisidetone circuit.

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b. Operation of circuit.—(1) *Transmitting.*—In the antisidetone circuit a different type of induction coil is used. The coil and circuit discussed here is taken from the EE-8-A telephone. This telephone uses an induction coil with one continuous winding tapped at terminals *2* and *3*, as shown in figure 22 so as to form the *1-2* section, *2-3* section and *3-4* section. When someone speaks into the transmitter the current through the *2-3* or primary section of the induction coil fluctuates with the change in resistance of the transmitter. These changes cause a voltage to be induced in the *1-3* or secondary section of the induction coil. For purposes of explanation, let us assume that an instantaneous current change in the direction *2* to *3* in the *2-3* section will cause a voltage to be induced in the *3* to *1* direction in the *1-3* section of the coil. The same current change will also induce a voltage in the *4* to *3* direction of the *3-4* section of the coil. Now consider that this induced voltage will cause current to flow out over the line and back to the point *C*,

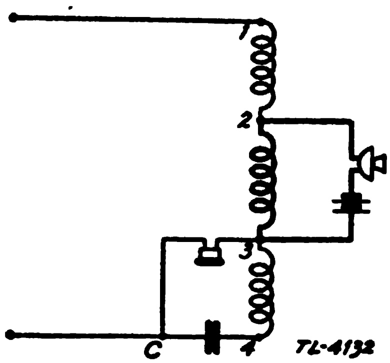


FIGURE 22.—A local-battery antisidetone circuit.

when the current reaches this point it has a choice of two paths. It can go through the receiver or through the *3-4* section of the coil. If it will be remembered the induced voltage in the *3-4* section was in such a direction as to aid this flow of current and if it is of such a value as to equal the *IZ* drop across the coil and condenser, there is no voltage drop between points *C* and *3*. Consequently no current will flow through the receiver. The condenser is not essential to the antisidetone circuit but its use makes possible a slightly better balance.

(2) *Receiving.*—The line current flowing through the *1-3* section of the induction coil induces a voltage in the *3-4* section in such a

direction as always to oppose the flow of this current through the *3-4* section of the coil and as a result the received current will take the alternate path through the receiver.

15. Questions for self-examination.—

1. Draw a schematic diagram of a receiver showing permanent magnets, pole pieces, windings and diaphragm.

2. What are the component parts of a local-battery telephone?

3. What is the function of a receiver?

4. Why is a permanent magnet used in a receiver?

5. Should direct current ever be passed through a modern receiver? Why?

6. Will a receiver act as a generator?

7. What are some of the troubles encountered in a telephone receiver?

8. Draw a schematic diagram of a telephone transmitter, show the electrical path through it.

9. Name some of the troubles inherent in a telephone transmitter.

10. Can a transmitter be used to generate a voltage? Why?

11. What is the approximate turn ratio of a local-battery induction coil?

12. What is the resistance of each winding?

13. What is the principle function of the induction coil?

14. When no one is talking what kind of current flows in the primary circuit? In the secondary circuit?

15. When someone is talking in the transmitter what kind of current flows in each case in question 14?

16. Explain the operation of a polarized ringer.

17. What kind of current will operate the ringer?

18. What is the resistance of an ordinary ringer?

19. Are the two windings in series or parallel?

20. Is it possible to leave a ringer bridged across a line during conversation? Why?

21. Draw a schematic diagram of a telephone magneto generator.

22. What is the frequency and voltage put out by a telephone generator?

23. What is the function of the ringer?

24. What is the function of the generator?

25. What is the function of the hook switch?

26. Draw a diagram of the local-battery telephone.

27. Name the four fundamental circuits of the local-battery telephones.

28. What is the battery voltage used in local-battery telephones?

29. Explain the operation of the antisidetone circuit.

SECTION III

THE LOCAL-BATTERY SWITCHBOARD

16. The need for switchboards.—Thus far two telephones connected by a pair of wires have been considered. This pair of wires might be called a line circuit. This system would work perfectly if each of these parties never wanted to talk to any one but the other party. However, ordinarily a man wants to be able to talk to any one of several people, perhaps one of hundreds or thousands. Consider the diagram shown in figure 23. This diagram shows four people

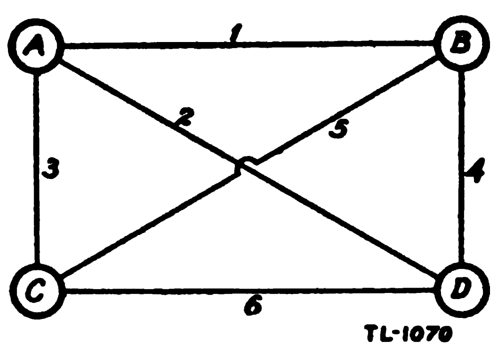


FIGURE 23.—Telephone net without switchboard.

A, *B*, *C*, and *D*, and each one desires to be able to talk to any one of the other three. Several disadvantages to such a hook-up are at once evident. In the first place, it requires six line circuits, and this number increases rapidly as the number of interconnected parties is increased. For example, five parties would require ten line circuits, six parties fifteen line circuits, etc. Thus, it would soon grow to be a very complex network, also a very expensive one. In the second place each of the parties shown in figure 23 must have three telephones, one for each line, or he must connect all three lines to one telephone. If he has three telephones, there is the cost to consider. Also, he must have a different sounding ringer on each, or he will not be able to tell which one is ringing unless the ringers are mounted a long distance apart. If he puts all three line circuits on one telephone he must use code ringing because every time he cranks his generator he will ring all three of the other parties' telephones. The result is loss of secrecy; if *A* and *B* were talking, *C* and *D* could overhear everything that was said. Thus it can be seen that without using a different scheme, even a small telephone system would be costly and complicated. There is one way of avoiding all this difficulty, and that is by the use of an additional piece of equipment called a switchboard. One line circuit is run from each telephone to this switchboard as shown in figure 24. The switch-

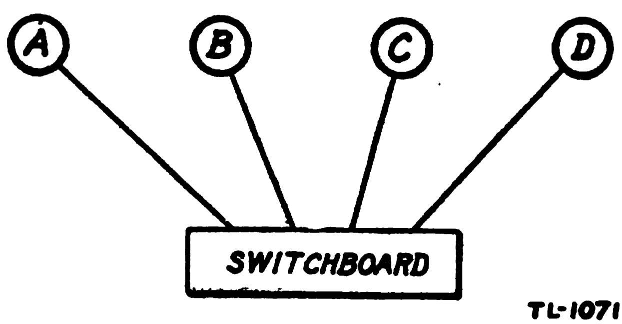


FIGURE 24.—Telephone net with switchboard.

board is located at the central office. An attendant, called the operator, is on duty at the switchboard, and it is this operator's job to make connections between these line circuits that come into the board. In order to do this several things are necessary. Assume that *A* wishes to talk to *D*. The following must be possible:

a. *A* must be able to signal the operator.

b. *A* must be able to let the operator know that it is *D* with whom he wishes to talk.

c. The operator must be able to signal *D*.

d. The operator must have means available at the switchboard so that he can easily interconnect *A* and *D* without the loss of time.

e. The operator must be able to determine when *A* and *D* have ended their conversation so that he can take the connection down.

17. The switchboard drop.—As stated above, the first thing the subscriber or telephone user must do when he wishes to talk to someone is to secure the attention of the operator. To do this he turns his generator crank and sends out 20-cycle ringing current. Because of the bulk of ringers and also the confusion that would result from attempting to locate the calling line, the use of ringers at the central office is impracticable. The situation calls for a small compact device, which, when energized by the ringing current, operates and displays a signal until such time as the operator answers the call. This device is called a drop and is a small electromagnet with a hinged armature. When ringing current is put through the magnet winding, the armature is attracted and a shutter is released on the face of the switchboard, giving visual indication to the operator that the line associated with that drop has signaled the central office. The schematic diagram of a switchboard drop is shown in figure 25 with the various parts named. Such a drop might not operate on weak signals because of leakage of the magnetic flux. In order to avoid this, some sort of return

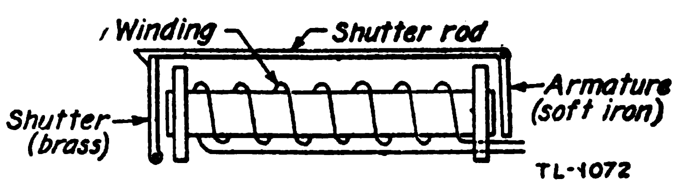


FIGURE 25.—Schematic diagram of local-battery switchboard drop.

path for the lines of force must be provided. This can be done by winding the magnet on two spools or by providing a soft iron bar for the return path. However, two spools make a bulky switchboard drop and the bar return path still allows much flux leakage. To eliminate these difficulties, the form of drop most commonly used consists of a single spool which is placed in a soft iron cup or

tube. This cup provides a magnetic return path and also prevents any straying or leakage of magnetic lines of force. Figure 26 shows side and end views of a drop of this type.

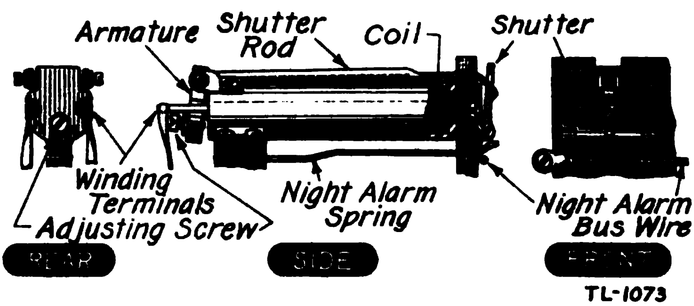


FIGURE 26.—Local-battery line drop.

There are several features of this drop that should be noted:

(1) The armature hangs between pointed pivot screws provided with lock nuts, and by means of these, the play can be taken out of the bearing.

(2) The terminals are at the rear of the device, permitting the armature to be adjusted, or wire connections to be resoldered, without disturbing the operator.

(3) The armature when attracted cannot make contact with the magnet core; thus it will not stick in the operated position due to residual magnetism of the core.

(4) The shutter rod is slightly bent near its hooked end where it passes through a hole in the shutter, so that when the armature is attracted, the inclined upper face of the rod strikes the upper edge of the hole in the shutter forcing the shutter outward and accelerating its fall. This makes the shutter operation positive in spite of any slight binding at the bearing or any small inclination of the axis of the drop. When a drop of this type falls, it must be rsetored manually by the operator.

18. The switchboard jack.—*a.* In the preceding paragraph the means by which a subscriber can signal the operator was discussed. The next step is to determine how the operator can make connection to the different lines. One method would be to bring the lines in on binding posts and provide the operator with clips for making the contacts. There are many systems that could be used, but the method that has been adopted as the quickest and most convenient

is to terminate each line circuit in a jack. Connections are then made to these jacks by means of plugs. These plugs and the circuit that goes with them will be discussed at greater length later. Figure 27 shows a diagram of one type of jack with a plug in it. Right below is shown the symbol of each. It will be seen from the diagram

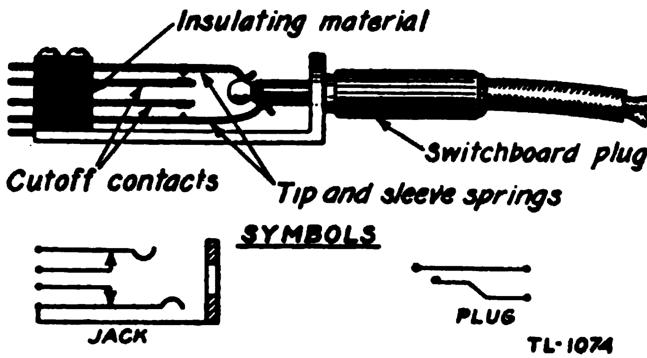


FIGURE 27.—Two-conductor plug and jack.

that the tip of the plug makes contact with the tip spring of the jack and that the sleeve of the plug makes contact with the sleeve spring of the jack. By variations in the number and arrangement of springs a jack can be made to perform simple switching operations when the plug is inserted.

b. Figure 28 shows a number of jacks that are used, with a statement of the function each performs. The jacks used in a local-battery switchboard are usually of the break-one or break-two type, and when the break occurs from the tip or sleeve springs they are called the single cut-off or double cut-off jacks.

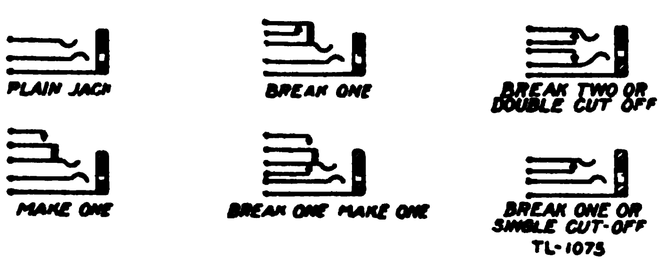


FIGURE 28.—Schematic diagrams of jacks.

19. Combinations of drops and jacks.—The jack is so closely associated with the drop in a line circuit that it is common practice to build them in one unit, known as the combined drop and jack. This has the following advantages:

(1) The jack is close to the signal with which it is associated.

(2) The wiring of the switchboard is simplified by shortening to a fraction of an inch, the leads connecting drop and jack.

(3) The drops may be made self-restoring, thereby speeding up switchboard operation.

Figure 29 shows a combined drop and jack and the leads to the telephone. It can be seen from the figure that the circuit through the drop winding is complete from the telephone, so that when the subscriber cranks his generator, ringing current passes through this winding and causes the armature to be pulled up. This allows

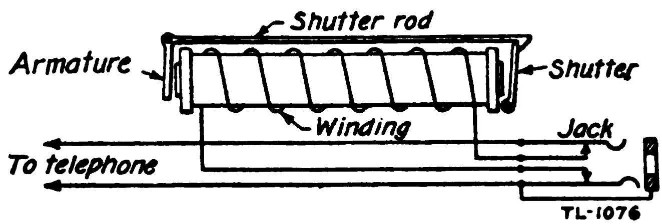


FIGURE 29.—Local-battery line circuit.

the shutter to fall and the operator knows that the subscriber has signaled the central office. When the operator inserts the plug in the jack, the drop is disconnected from the line. Just how the operator is able to talk with the subscriber and determine what number or party the subscriber desires to talk to will be discussed later.

Figure 30 shows a picture of a Western Electric combined drop and jack with a self-restoring device; *a* shows the operated position with the shutter down and *b* shows how the shutter is restored when the plug is inserted. The night alarm spring is shown in figure 26. When the shutter is down the circuit between this spring

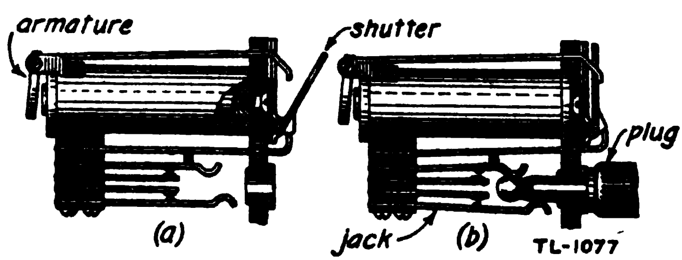


FIGURE 30.—Self restoring line drops.

and the night alarm bus is closed, and the circuit is open when the shutter is up in the normal position. These are the night alarm

contacts, the function of which will be discussed later in connection with the miscellaneous circuits of a switchboard. The night alarm spring has been omitted from figure 30.

20. Constructional features of drops and jacks.—The magnet coils for drops are wound to a total resistance of from 80 ohms to 1600 ohms, the latter being the more sensitive. The core is of solid soft iron and the spool ends are usually of fibre about 1/16 inch thick. The spool is usually about 1/2 inch in diameter and about 2 3/4 inches long and is so mounted that the armature cannot make contact with the core. The combined drops and jacks are screwed to metal plates mounting from five to ten in a group and these plates are secured in the face of the switchboard. Thus the drop shutters appear in horizontal rows across the face of the switchboard and below each shutter is its associated jack.

21. Purpose and description of cord circuits.—Line circuits always terminate on jacks in the switchboard. A drop is immediately associated with each jack. The use of jacks for terminating line circuits furnishes an easy and rapid method of making connection to the line circuits. For making this connection, plug-ended circuits are used. These circuits are called cord circuits and ordinarily are terminated by a plug at each end. The plug consists of three main

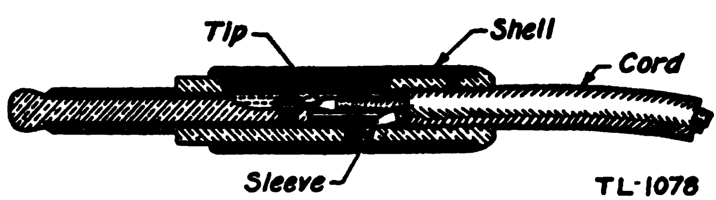


FIGURE 31.—Two-conductor switchboard plug.

parts; namely, a rod terminating in a ball, a tube fitting over the rod and insulated from it, and a shell which covers the rear end of the rod and tube and protects the connections of these parts to the cord. Figure 31 shows a plug in cross section. The ball is known as the tip and makes contact with the shorter or tip spring of the jack, while the tube is known as the sleeve and makes contact with the longer or sleeve contact of the jack. Refer also to figure 27.

22. The patching cord.—The simplest form of a cord circuit consists of a pair of conductors with a plug at each end. This type is known as a patching cord. Figure 32 shows a diagram of two lines

connected by such a cord. The two parties connected as shown above can converse perfectly over such a cord circuit, after the connection is once established. But so far there is no means by which the calling party (the one who places the call) can talk to the operator and tell him with whom he wants to talk. There is also no means by which the operator can signal to any party, nor is there any means which will tell him when the two people are through talking.

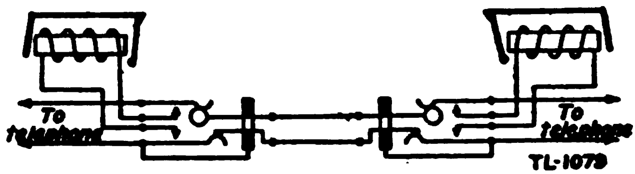


FIGURE 32.—Patching cord circuit.

23. **The operator's telephone.**—The first thing to do is to provide the operator with a telephone set so that he can talk to the subscriber and hear what the subscriber says. In order to obtain this two-way conversation when we use two telephones, it is necessary that:

(1) A receiver and secondary in series be placed across the line, and

(2) A primary circuit consisting of a transmitter, battery and primary of the induction coil be complete and coupled to the line by means of the induction coil. If we make this addition to the simple cord circuit it will look like figure 33. Now if a party places a call by ringing, the drop falls, calling attention of the operator,

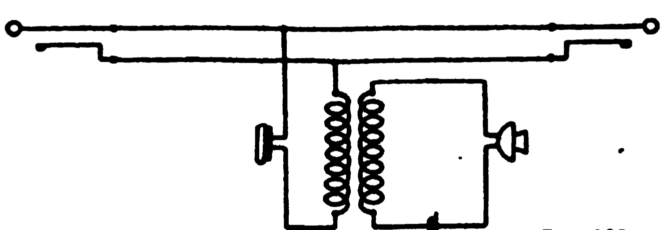


FIGURE 33.—Patching cord with operator's set.

whereupon the operator may place one of the plugs in the jack and can then talk with the subscriber, and the subscriber can tell the operator the number or party he wants. If the operator's telephone

were to be connected exactly as shown in figure 33, it would have some defects. In the first place, the telephone is permanently connected to the cord circuit. This is not desirable, as will be seen later, so there should be some means of connecting and disconnecting the telephone from the cord circuit at will. Secondly, the primary circuit is closed at all times; therefore current is flowing whether the operator's telephone is in use or not. To overcome these disadvantages a switching device called a listening key is used. Figure 34 shows a schematic diagram of two listening keys. Spreading the two center springs causes the contacts to make. A key of

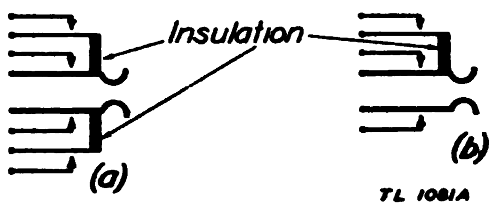


FIGURE 34.—Types of listening keys.

type shown in figure 34a is placed in the cord circuit as shown in figure 35. As can be seen from figure 35, operating the listening key will connect the operator's set to the cord circuit. It will be noticed that there are two unused contacts of the key. It is common practice to make keys as shown, but in this type of cord circuit, two of the contacts are useless.

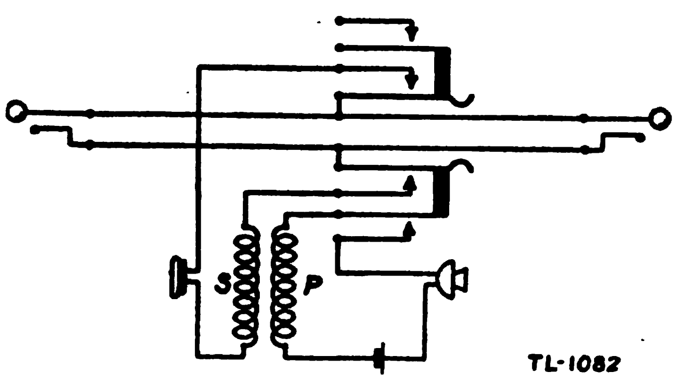
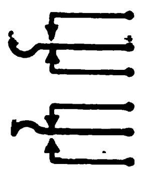


FIGURE 35.—Cord circuit with listening key.

24. Ringing keys.—The next thing that must be added to the cord circuit is a device so that the operator can ring the called party (the one with whom the calling party desires to talk). An ordinary

hand generator can be used as the source of ringing current, but it must be connected in such a way that ringing the called party will not ring in the ear of either the operator or the calling party. To accomplish this end a ringing key is used. Such a key is shown in figure 36. This key is of the break-two, make-two type. Some local-battery cord circuits use two of these keys in each cord circuit, one associated with each plug so that the ringing current may



TL-1083

FIGURE 36.—Ringing key.

be put out from either plug. Figure 37 shows how these two ringing keys are placed in the cord circuit. From the diagram it can be seen that operating either ringing key and cranking the generator puts ringing current out through that key's associated cord and plug, for the ringing key opens the circuit to the other cord by means of its break contacts.

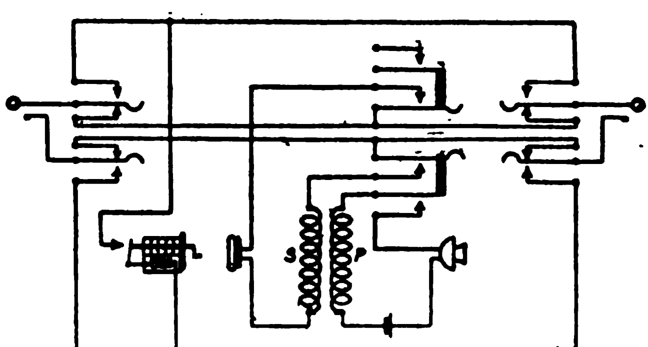


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FIGURE 37.—Cord circuit with ring and ring-back keys.

25. Supervision.—There still remains one more addition to be made to the cord circuit, and that is a device to indicate to the operator when two people have finished a conversation. The simplest way to do this is to bridge a drop, similar to the ordinary line drop, across the cord circuit. When a conversation is finished, the subscribers should ring off. This will operate the drop, which is called

a clearing out or supervisory drop, and let the operator know that the conversation is completed. Figure 38 shows the cord circuit with this supervisory drop added. The diagram is a typical local-battery cord circuit. The operator would be unable to tell which party had rung off, but he should throw his listening key and challenge before taking down the connection. Then if one party is trying to place another call, the operator can ask and find out which one it is. This method of using just one supervisory drop for each cord circuit is called single supervision. There is another method called double supervision in which two supervisory drops are used with each cord circuit, but this is not so common as single supervision.

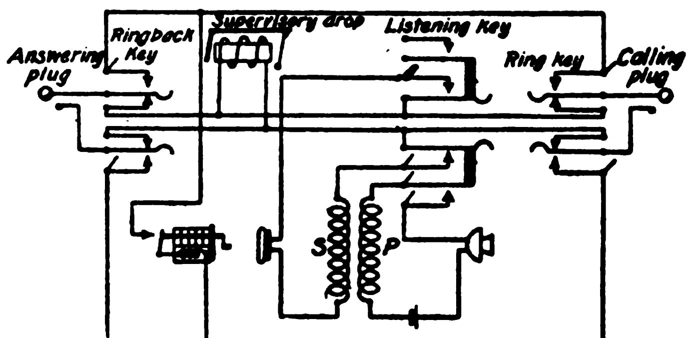

FIGURE 38.—Local-battery cord circuit complete.

26. Location of cord circuit parts in switchboard.—The next thing is to find out just where the various parts of the cord circuit appear

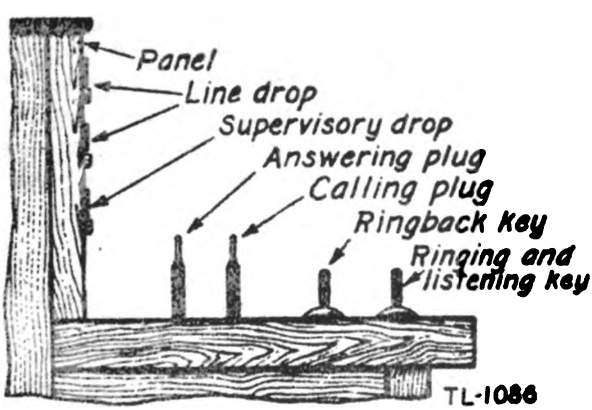

FIGURE 39.—Switchboard key shelf, side view.

on the switchboard. The two plugs which are the ends or terminals of each cord circuit are located in plug seats on the key shelf of the board. One plug is directly in front of the other. Next and right in line with the two plugs appear the two key levers. On the face of the board and directly in line with the keys and plugs is the cord circuit supervisory drop. This drop is usually in a row below the line drops and can easily be distinguished from a line drop in that it has no associated jack. Figure 39 indicates more clearly the location of this equipment on the switchboard. The plug farther from the operator (one nearer panel of board) is the answering plug. This is the plug the operator uses to answer a calling subscriber. The ringing key associated with the answering plug is the ring-back key. The front plug of a pair (the one nearer the operator) is the calling plug and its associated key is the ring key or ringing key. These parts are labeled in figure 38. It is common practice in local-battery switchboards to associate two of the three keys together so that the two can be controlled by one lever. In many switchboards the listening and ring keys are associated together; pushing the lever away from the operator closes the listening key (lever locks in this position) while pulling the lever toward the operator puts ringing current out through the calling plug. Figure 38 shows these two keys controlled by one lever. In some switchboards the ring and ring-back keys are associated together.

27. Double supervision.—It was mentioned in a preceding paragraph that most local-battery switchboards are of the single supervision type. This is true of nearly every board, but it might be well to show how double supervision could be obtained. Figure 40 shows a cord circuit with this type of supervision. The ringing and listening keys are omitted from the diagram. The capacitors offer a great deal more opposition to ringing current than to voice frequency currents. By means of such a circuit the operator can tell when either or both parties ring off. However, it does have two disad-

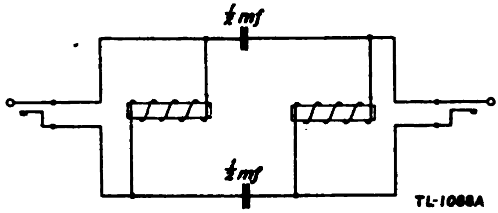

FIGURE 40.—Partial cord circuit showing double supervision.

vantages and is, therefore, seldom used in practice. In the first place there is the added equipment, and ordinarily this is not worth while on a local-battery switchboard. Secondly, the capacitors in series with, and the two drops bridged across the line cause transmission loss in the circuit.

28. Repeating coil cord circuit.—Sometimes line circuits are composed of only one metallic conductor, ground being the other side of the circuit. In making connections at a switchboard where either or both lines are of this type, it is often desirable to keep the lines physically separate. In doing this the noise will be reduced to a minimum. To accomplish this a repeating coil cord circuit is used. The two halves of the cord circuit are physically separated but inductively coupled to each other. The repeating coil is a special type of transformer with four windings, but for this discussion it can be regarded as a highly efficient one to one ratio transformer. A diagram of such a cord circuit (omitting keys) is shown in figure 41. This circuit is of the single supervision type.

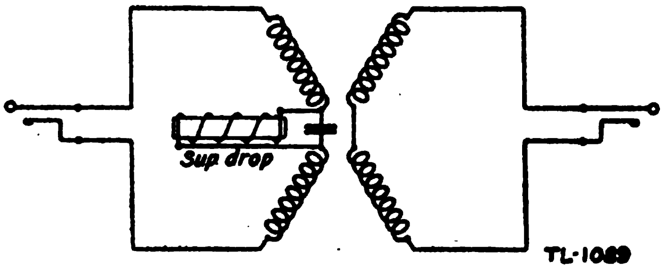

FIGURE 41.—Partial repeating coil cord circuit.

29. Common connections of cord circuits.—In an ordinary local-battery switchboard of from 50 to 100 lines capacity, there are usually from six to fifteen cord circuits. Thus there will be a row of ringing and listening keys, one of ring-back keys, one of calling plugs, one of answering plugs, and one of supervisory drops appearing as the visible parts of the cord circuits. These different parts are interconnected by wiring which pertains to each cord circuit only.

It is this wiring of one cord circuit which has been shown in the preceding figures. There are, however, additional connections which are common. For example, in a switchboard there is but one operator's telephone and one hand generator, and it is necessary to use this one with every cord circuit. This means that certain contacts of one cord circuit must be wired in common to the cor-

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responding contacts of every other cord circuit in the switchboard. These common points of the cord circuit are indicated in figure 38 by means of short oblique lines. This symbol will be used in subsequent drawings, where it is necessary to indicate that parts are wired common.

30. Questions for self-examination.—

1. Draw a diagram of a drop showing the winding, shutter, shutter rod and armature.

2. What means has been adopted commercially to prevent magnetic lines of force from one drop straying to another?

3. Show by a diagram the electrical connection between a drop winding and the associated jack.

4. Draw a diagram of a make-one break-one jack.

5. What is meant by a double cut-off jack?

6. Give two advantages of having the drop and associated jack built as one unit.

7. How is the operation of a shutter made positive?

8. How are drops and jacks mounted on a switchboard?

9. How are the shutters restored on most switchboards?

10. What is the resistance of a drop winding?

11. What is the disadvantage of using two spools in a drop?

12. Draw a diagram of a magneto telephone set, include the line connecting it to the switchboard and the switchboard equipment immediately associated with it.

13. Would direct current operate a drop? Why?

14. What is a cord circuit?

15. How are cord circuits usually terminated?

16. Why are repeating coils sometimes placed in cord circuits?

17. What is the difference between single and double supervision?

18. Why is it necessary to remove the calling party from the line before ringing the called party?

19. What type of local-battery supervision is usually found on signal corps boards? Why?

20. Are ring-back keys used on all local-battery telephone switchboards?

21. Why is a ring-back key desirable?

22. Are ringing keys ordinarily of the locking type? Why?

23. Draw a diagram of a two-conductor plug.

24. Make a diagram of a listening key. Draw a diagram of an operator's telephone set and properly connect it to the key.

25. Show how you would connect an operator's transmitter and receiver to a twin plug. Why is it connected this way?

26. Draw a diagram of a complete local-battery cord circuit, including a generator circuit and the operator's telephone set, which will have the following features:

a. Ringing on answering cord without ringing on calling cord.

b. Ringing on calling cord without ringing on answering cord.

c. Means for operator listening on cord circuit only when listening key is closed.

d. Means for operator talking on cord circuit and primary circuit completed only when listening key is closed.

e. Supervision by operator.

SECTION IV

MISCELLANEOUS SWITCHBOARD EQUIPMENT

31. Definition of miscellaneous circuits.—Under the heading of miscellaneous circuits are grouped all circuits of a local-battery switchboard except line, cord, and operator's telephone circuits.

32. Night alarm circuit.—This circuit is found on every switchboard. Its purpose is to give an audible as well as a visual signal every time either a line or supervisory drop is operated. At the bottom of each drop there is a contact spring which normally

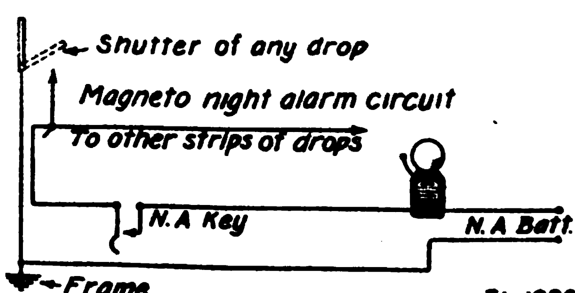

FIGURE 42.—Night alarm circuit.

stands open from the frames, but is closed against the frame by the shutter when it falls. In a switchboard all of these contacts are wired common. The common wire is then connected in series with a locking key, an electric bell, two or three dry cells, and a ground connection. When the key is closed, the night alarm circuit will be

completed by the falling of any line or supervisory shutter, and the bell will ring until the shutter is restored or the key is opened. For normal use the night alarm circuit is rendered inoperative by opening the key. At night or other times when the operator is away from the board but on duty, the key should be closed. A typical circuit is shown in figure 42.

33. Generator switching circuit.—When the exchange is provided with a source of ringing current other than the hand generator, a generator switching circuit is required. This is controlled by a key which functions as a double-pole double-throw switch and enables the operator to change from one source of ringing current to the other. Figure 43 shows such an arrangement.

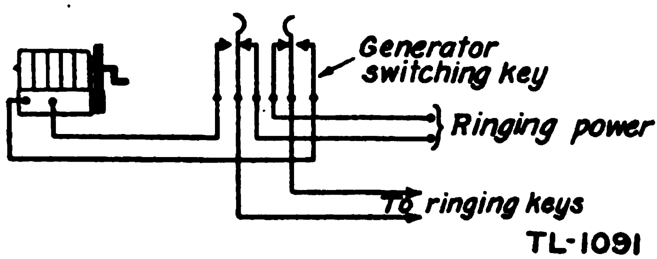

FIGURE 43.—Generator switching circuit.

34. Trunk circuits.—*a. General.*—Trunk circuits are line circuits used to terminate trunk lines or trunks which connect two switchboards together. They are a variation of a normal line circuit. A local-battery trunk circuit, in its simplest form, consists of a drop and jack. This circuit is the same as the normal line circuit, and its operation is the same as for any local-battery line circuit.

b. Common-battery trunk circuit.—When local-battery switchboards are connected by trunks to common-battery switchboards, special circuits must be used at one of the switchboards. If the trunk comes in on an ordinary line circuit at the local-battery end, the special equipment will be at the common-battery switchboard. This equipment will not be discussed in this text. If, however, the trunk terminates on a line circuit at the common-battery exchange, then the special arrangements must be made at the local-battery end. A short circuit placed on a common-battery line circuit by a local-battery drop would permit the flow of direct current from one side of the line through the drop to the other side bringing in the signal on the common-battery board. It would also operate the drop

at the local switchboard. The solution of the problem then requires that a special circuit be developed to provide proper operation. Provision must be made to give the proper signals to the common-battery switchboard both for calling and supervision. This can be accomplished by the circuit shown in figure 44. This trunk circuit will terminate a common-battery manual trunk and satisfy all of the above conditions. First, consider the operation of the circuit for an incoming call. Twenty-cycle ringing current is applied by the distant operator and the drop associated with the trunk circuit on the local switchboard will fall. The local operator then plugs the

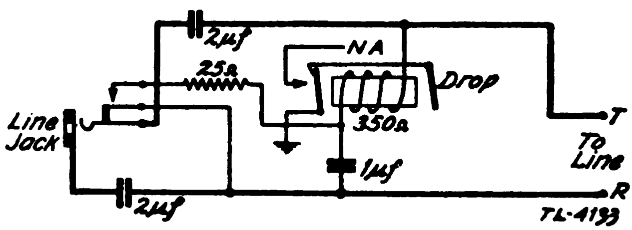

FIGURE 44.—Common-battery trunk circuit.

answering cord into the line jack. This closes the make contact on the line jack which sets up a circuit through the drop winding and the 25-ohm resistor which holds the supervisory relay at the distant switchboard operated. The call is now completed by the local operator. When the conversation is completed the local subscriber rings off, and the supervisory drop on the cord circuit will drop. The local operator then takes down the connection, opening the loop to the distant switchboard and giving the distant operator a disconnect signal. When the call is outgoing the local operator merely plugs into the line jack which closes the direct-current loop described above. This causes the line lamp associated with this line to light and the distant operator handles the call the same as for a local call.

35. Interposition trunks.—In some cases where several local-battery switchboards are grouped together as positions of one large switchboard, each position is equipped with trunks to each other position. This is to enable a line on one position to be connected to a line on some other position. These trunks may be unnecessary between adjacent positions as the cords may be long enough to reach from one position to the next.

36. Through line circuit.—In cases where the switchboard is at an intermediate point on a through line, a switching arrangement is sometimes used to provide for its being used either way or both ways from the intermediate office. This is accomplished by the equipment shown in figure 45 and consists of two double cut-off jacks and a combined drop and jack. This equipment is wired as

FIGURE 45.—Through line circuit jack arrangement.

shown in figure 46. When this apparatus is used, code ringing must be used on the line. When the operator at the intermediate station sees the shutter fall and hears the shutter-rod rattle with his code,

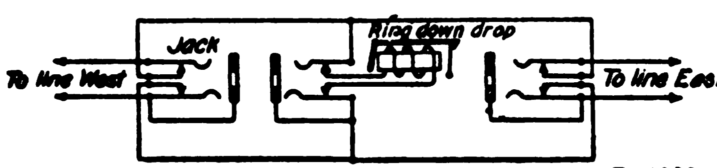

FIGURE 46.—Circuit diagram for through line circuit.

he answers by plugging into the middle jack. If the call is for a subscriber connected to his board, he ascertains whether the call is from line east or line west. If the former is the case he transfers his plug into the right-hand jack and completes the call in the usual way. This leaves the drop bridged across line west and the intermediate operator must answer calls on this line for his station and for the stations east of him, in the latter case notifying the calling operator that the line east is busy. In the case of a call originating at the intermediate office the operator, before calling east or west, should go in on the line through the middle jack and listen to insure that it is not in use. Having determined that the line is idle, the operator can plug into the left-hand jack and ring to call over line west or into the right-hand one for line east. When either line, east or west, is left because of an outgoing call, the operator must an-

swer all calls from distant stations for his station and for those on that portion of the line being used as previously described.

37. Transfer circuits.—When, on a two-position switchboard, the load is so light that one operator can handle all the calls, as at night, it is customary to use only one operator. As long as he handles all the calls with the cords of his position no complications arise. But there may be some cases where he must use the cords of the other position. In order to do this and save him the trouble of changing receiver and transmitter, his receiver and transmitter must be connected into the telephone set associated with this other set of cord circuits. The circuit used for this purpose is called a transfer circuit.

38. Ringing machines.—*a. The "Telering."*—This instrument was devised to produce a 20-cycle ringing current from a 110-volt 60-cycle power input. It is included as part of the Telephone Central Office Set TC-4. The principal of operation of the Telering is the utilization of two frequencies to produce a beat frequency. This beat frequency is the difference between the 60-cycle input and the resonant frequency of a vibrating reed. Figure 47 is a schematic diagram of the Model "H" Telering. Fundamentally, it has the same circuit as other models. By referring to figure 47, let us assume that the instant the circuit is closed, current is flowing in at L-1, through the fuse and the primary of the transformer and through the other fuse to L-2. A voltage is induced in the secondary of the transformer in the direction of the arrow to point *A*. Here the resulting current divides, part flowing through the 50-watt lamp and the output load, and part through the 2000 ohm resistor and winding of the motor coil. The current flows through these two circuits and joins at the vibrating reed. From the vibrating

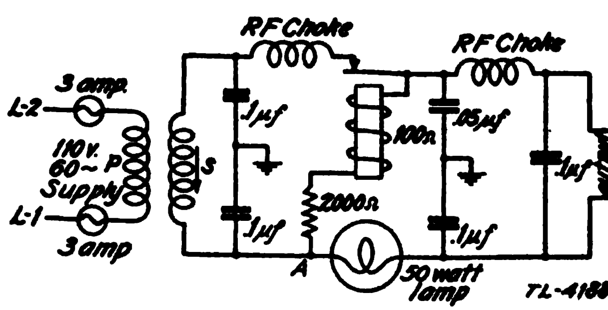

FIGURE 47.—Model H Telering.

reed it flows through the radio-frequency choke and back to the secondary of the transformer. As long as the circuit is closed between the vibrating reed and its contact, current will flow through the output load. This first half cycle, or alternation, through the motor coil, causes the reed to sweep toward the motor coil, opening the circuit. The circuit being opened, the motor coil de-energizes and the reed sweeps back and closes its contact. In this manner, the reed is kept vibrating continuously. The contact at the reed, being common to both the motor coil and the output, allows an impulse to go through the 50-watt lamp to the output each time the contact is closed.

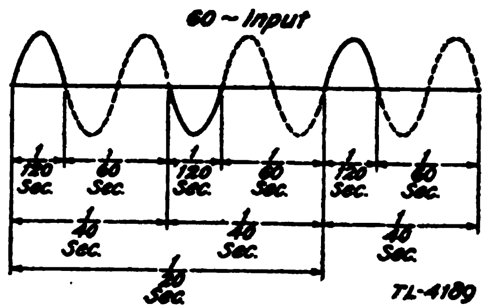

FIGURE 48.—20-cycle output of Telering.

Due to the characteristics of the tuned vibrating reed, the contact is closed for $\frac{1}{120}$ of a second and open for $\frac{1}{60}$ of a second. The input is 60 cycles, or 120 alternations per second; therefore, each alternation takes $\frac{1}{120}$ of a second. When the contact at the reed is closed for $\frac{1}{120}$ of a second, one alternation is permitted to flow through the output. The contact is then opened for $\frac{1}{60}$ of a second and two alternations of the input are missed and not allowed to flow through the output. It can be seen from figure 48 that 40 alternations or 20 cycles are selected per second, and are allowed to flow into the output.

b. The "Sub-cycle" static frequency converter.—This apparatus is a frequency reducing device which furnishes ringing power at a sub-multiple of the power supply frequency. The Sub-cycle does not use any moving parts while operating. They are available for operation on 115-volt 60-cycle and for 115-volt 50-cycle power. For other commercial voltages at these same frequencies, a transformer is inserted between the converter proper and the power supply line, so as to bring the input voltage within the rating of the device,

as given on the name plate. The output frequency of the Sub-cycle is one-third of the input frequency. The maximum output is 20 watts which is sufficient to operate 25 ringers simultaneously with average line conditions. The output voltage at no load is 90 volts across the secondary winding. From no load to full load, the output voltage drops no more than eight volts.

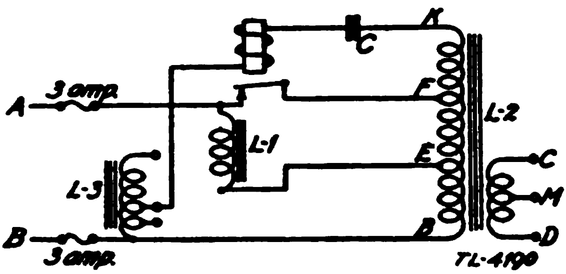

FIGURE 49.—"Sub-cycle" static frequency converter.

(1) *Starting.*—The 115-volt 60-cycle supply is applied to points *A* and *B*, figure 49 through the three ampere fuses. With the relay at normal, the input supply is connected to the winding FB of transformer L–2. The transformer operates as a 60-cycle auto-transformer at this time, stepping up the voltage to approximately 440 volts across its winding KB. This high voltage is applied to the 8 μf. capacitor C through L–3 and the relay winding. The resistance of L–3 and the relay winding is approximately 2 ohms each and have a negligible effect on the charging current of the capacitor. A large charging current rushes into the capacitor, energizing the relay. The operating time of the relay is such that it operates about the time capacitor C has charged to the peak value of the 440 volts. The operation of the starting relay allows the charge stored on the capacitor to discharge through winding KB of transformer L–2, causing a starting current to flow through series inductance L–1. Thus, the resonant circuit formed by inductance L–3 and the capacitor C coupled by the transformer L–2 is started oscillating at its resonant frequency of 20 cycles per second. In this particular case, choke coil L–1 is a low resistance inductance which saturates sharply with voltages greater than 115 volts at 60 cycles.

(2) *Operation.*—While the 20-cycle circuit is oscillating freely, there will be successive times when the potentials of the 60-cycle supply and the 20-cycle oscillations counteract current flow through L–1 and other times when they do not. For the former condition

L-1 will have a high impedance. But for the latter condition L-1 will saturate and have a low impedance. Thus, a large current flows from the 60-cycle source when in a direction to aid the flow of the 20-cycle current; but a very small current from the 60-cycle source flows at all other times due to the high impedance of L-1 when not saturated.

(3) *Restarting.*—In case of a momentary overload, the external load requires so much power that the circuit will be unable to maintain the 20-cycle oscillations. As soon as the oscillations through capacitor C and winding KB stop, the relay will release and automatically restart the converter. In case of a prolonged overload, the capacitor C will be repeatedly charged by the automatic restart operations of the relay. The successive large charging currents will burn out the three ampere fuses to protect the machine. The relay has no function in the normal operation of the converter, but plays an important part in automatically starting and restarting the machine. The Sub-cycle requires only 20 watts no load power, which demonstrates its economy of operation, even where continuous operation is necessary. Stability of the converter is not affected by relatively wide variations in either the frequency or the voltage of the commercial a-c supply. A self-regulating characteristic maintains better voltage regulation of the output than any attempt at regulation of the input voltage.

39. Questions for self-examination.—

1. What is meant by a miscellaneous circuit in a switchboard?

2. Name five miscellaneous circuits.

3. What is a trunk circuit?

4. What is a transfer circuit?

5. Draw a diagram of a night alarm circuit.

6. Draw a diagram of a bell that can be operated from dry cells.

7. Could a ringer be used as a night alarm bell? Why?

8. Assume that you have two sources of ringing current available, hand generator and power ringing. Show by a diagram how you could change from one to the other at will.

9. Draw a diagram of a through line circuit containing the following features:

a. A means of signaling when either line east or west rings.

b. A means for talking with both line east and line west at the same time.

c. A means for cutting off line west when talking to line east.

d. A means for cutting off line east when talking to line west.

SECTION V

DISTRIBUTING FRAMES

40. Purpose of distributing frames.—In addition to the switchboard, a central office is equipped with facilities for permanently terminating the incoming lines and distributing them to the various jacks. It is the purpose of this section to give a description of the distributing frames found in various size offices. It is important that the functions of these frames be thoroughly understood. The principal function is to provide means for terminating the outside lines and also the switchboard lines in a permanent and orderly manner, and at the same time provide facilities for changeably interconnecting these permanently terminated lines among themselves by means of jumpers or cross connecting wires. The MDF (main distributing frame) is a natural dividing point between the outside plant and inside plant or between the outside lines and the switchboard lines. Therefore the MDF is the logical location of the central office protectors, to be discussed in a later section, which guard the inside plant from all outside hazards. The fact that all outside lines and all inside lines are permanently terminated on the MDF in such manner as to be readily identified and easily accessible, without disturbing any of the permanent wiring, makes the main frame the most convenient point from which to conduct many of the tests that are required both on the outside and inside lines. Finally, the use of another type of distributing frame makes it possible to shift the load of different operators and to change subscriber's numbers. This may not seem very important in a small office with one non-multiple board, but in a large exchange with a multiple board it is

of utmost importance. In fact without the use of such frames the wiring in a large central office would be a hopeless tangle.

41. Distributing frames for small offices.—Distributing frames are divided into two classes; wall and floor frames. In most small offices the wall type frame is used; however, this will vary with local conditions such as probability of expansion, type subscriber served, etc. In small army exchanges that use the switchboard BD-80 or BD-89, floor type frames are used. For the very small commercial installations with 80 or less lines, the wall frame is built up of units each one of which will take care of 20 pairs. This is the simplest form of frame and consists of two terminal blocks. The pairs from the outside are fastened to contacts on one block and the pairs running to the board are fastened to the other block. The two blocks are then interconnected by wires called jumpers, which can be fastened to any desired set of terminal lugs on either end. These jumpers are run through rings in order to make a neat and orderly arrangement and to aid in tracing out circuits. All connections are made by soldering. In actual practice protective devices are mounted on either one or the other of these terminal blocks. By the use of such a simple frame a place is obtained for mounting protective devices and also a convenient place to open the circuits for testing purposes. Schematically the circuit through the frame is as shown in figure 50.

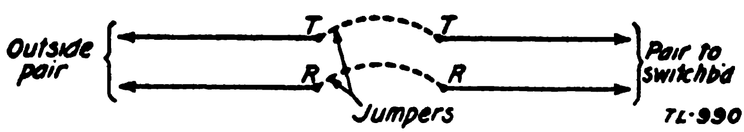

FIGURE 50.—Connections through a distributing frame.

42. Types of floor frames.—In general floor frames are of three classes:

(1) Those that have two vertical sides as the FM-19 (TC-1) and BE-79 (TC-2). This type frame is used in smaller army exchanges.

(2) Those that have one side vertical and the other side a combination horizontal and vertical. This type is used in larger army exchanges and will be discussed later.

(3) The other type of floor frame is the standard frame that has one side vertical and the other horizontal. On all floor-type

frames the two sets of terminal blocks are on opposite side of the frame. Usually they are arranged in vertical rows on one side and horizontal rows on the other. These two sides are then referred to as the vertical and horizontal sides respectively. Figure 51 shows part of a typical distributing frame. The protectors are mounted on the vertical side. On the horizontal side are found the terminal blocks; each mounted in a horizontal position. When the vertical side is the switchboard side the frame is known as a type A frame. With the horizontal side connected to the board, it is known as a type B frame. The bridle rings are to assist in an orderly running of jumper wires between protectors and terminal blocks.

43. Distributing frames for large exchanges.—In large exchanges where all switchboards are of the multiple type, there is a great increase in the amount of central office wiring necessary. Thus a more elaborate system of distribution is required. To accomplish this it is common practice to use two distributing frames and, to

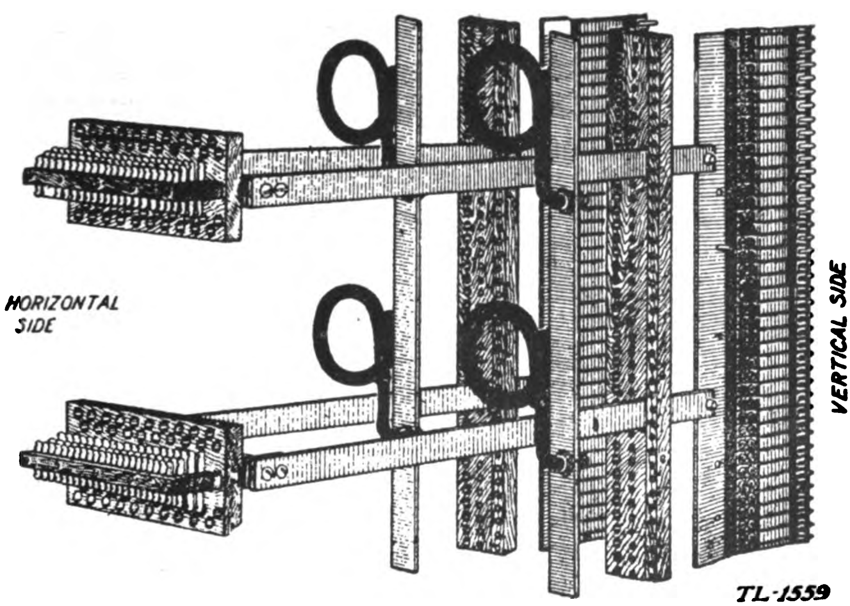

FIGURE 51.—Floor frames.

distinguish between them, they are known as a main frame and intermediate frame. Each of these frames has a vertical and a horizontal side. The protectors are mounted on the vertical side of the main frame and it is to this side that the outside pairs are

attached. Figure 52 shows the manner in which connections are made through the two frames. In the diagram, VMDF means ver-

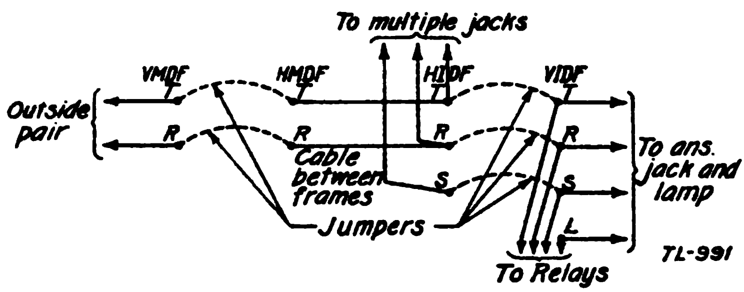

FIGURE 52.—Connections through standard MDF and IDF.

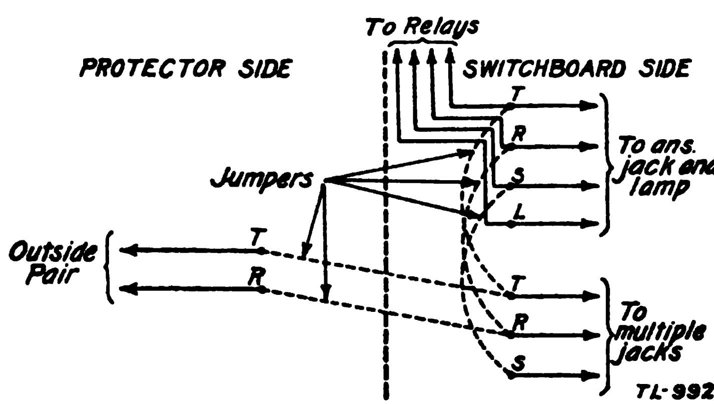

FIGURE 53.—Connections through combination MDF and IDF.

tical side of main distributing frame, etc. It will be noticed that two-wire jumpers are used on the main frame and three-wire jumpers on the intermediate frame. Since the telephone number is determined by the multiple jack to which the telephone is connected, the numbers of telephones are changed by shifting jumpers on the main frame. The load of the operators can be varied by shifting jumpers on the intermediate frame. The above means of distribution is used in all large commercial exchanges.

44. Distributing frames for larger army exchanges.—In some of the larger exchanges in the service which use multiple boards, a means of distribution is used which differs somewhat from the system des-

cribed above. One frame known as combined frame is used instead of the two. This method, of course, costs less but also some of the advantages of having the two frames are lost. The protectors are mounted on the vertical side of this frame as before and the outside pairs terminate on this side. The other side of this frame is a combination horizontal and vertical side, the lower half being horizontal and the upper half vertical. The lower half corresponds to the HMDF and HIDF, thus doing away with the cable that was used between frames and shown in figure 52. The upper half corresponds to the VIDF. Thus the two sets of jumpers are used on the one frame. Figure 53 shows a schematic diagram of this arrangement.

45. Switchboard cables.—From the distributing frame it is universal practice to conduct the lines to the switchboard in switchboard cables. With 100-line and smaller boards, it is not uncommon to use a single cable to carry all the pairs. With some small boards and all larger ones, it is common practice to use as many 20-pair cables as may be required. These cables are usually a flat oval in cross section, so that they will pile evenly and maintain their place on the cable rack. The pile of cables is laced together and to the cable rack which supports it. This same type of 20-pair cable is used between the HMDF and HIDF in all large exchanges.

46. Cables from outside plant.—The cables of the ouside plant are usually more easily introduced from below to the distributing frame. If the plant is underground construction, the entrance will be made from the cable vault, and if the plant is aerial, the entrance will usually be made through iron pipes which are brought down the office pole and come up beneath the distributing frame. In a small office with a wall frame aerial cables are often brought to the office by means of a cable rack extending from the building to the office pole.

47. Questions for self-examination.—

1. What is a distributing frame?

2. What is the purpose of using a distributing frame in a central office?

3. Describe the wall type of frame.

4. What type frame is used in a small office?

5. How is a jumper connected to the terminal contacts?

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6. What type of main frame is used in a large exchange?

7. What is the difference between a type A main frame and a type B?

8. Upon which side of a main frame are the protectors mounted?

9. Under what conditions is it most practicable to use separate main and intermediate frames?

10. When is it practicable to use a combined MDF and IDF?

11. How many conductors are there in an MDF jumper?

12. How many conductors are there in an IDF jumper?

13. Draw a diagram tracing a circuit through separate MDF and IDF. Show which leads go to the multiple, the jack and the outside pair.

14. By what means is the HMDF connected to the HIDF?

15. How are outside cables usually brought in to the main frame?

16. Draw a diagram tracing a circuit through a combined MDF and IDF.

SECTION VI

CENTRAL OFFICE PROTECTION

48. Types of hazards.—*a. General.*—Telephone apparatus must be protected against electrical hazards which may be due to either natural or artificial causes. Lightning is the only noteworthy example of a natural hazard. Artificial hazards may be created from sources outside the telephone plant, such as excessive voltages or currents induced in the telephone wires from electrical systems and high power radio sending apparatus, being in close proximity to telephone lines; or from sources within the telephone plant, such as the accidental flow of current from the plant power supply in unexpected channels or in abnormal quantities.

Protective equipment must be provided to safeguard persons and property against all such hazards. All protective devices are designed so as to function properly before any damage to plant occurs, but they must not be so sensitive as to cause unnecessary interruptions to service.

b. Classification of protective equipment.—Practically all outside telephone plant, except such conductors as are completely underground from terminal to terminal, may be exposed to one or more of these foreign hazards. Therefore whenever exposed wires are led into a central office or subscriber station, they are connected first through certain protective devices. The particular protective units employed and the manner in which they are connected into the telephone circuits vary somewhat with particular situations, but in general protective devices are classified as to the type hazard they are intended to guard against:

(1) Those forming a protection against small currents which become a hazard only when flow continues for an appreciable length of time. The heat coil is an example of this type.

(2) Those forming a protection against excessive currents. The fuse is an example of this type.

(3) Those forming a protection against excessive voltages. The air-gap arrestor is an example of this type.

In large exchanges where incoming cable is all underground, it is the practice to omit protector blocks and heat coils and to replace them with dummy apparatus. The only function the protector mounting serves in this case is to provide means for opening the lines for test purposes.

49. Heat coils.—*a. Common type.*—A heat coil consists of a small coil of resistance wire wound around a metal collar to which one end of the wire is soldered. The collar in turn is fastened by a low melting point solder to the core. The whole is contained in a fibre shell for mechanical protection and heat insulation.

Heat coils are designed to protect against low potential currents. They operate on a small amount of excess current supplied over a period of time. The accumulated heating effect of the small current passing through the winding finally melts the low melting point solder and allows the core and the collar of the device to move with respect to each other. A Western Electric heat coil is installed with one end of the core pressing against a spring and when the coil operates, the core presses this spring in until it makes contact with ground. Thus, a heat coil in operating does not open the circuit but

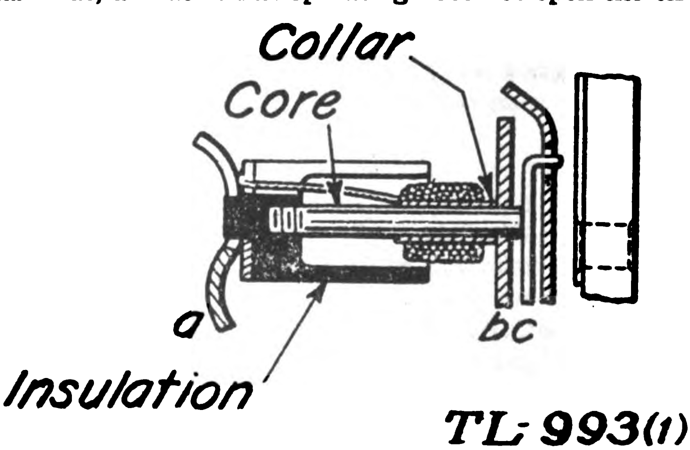

FIGURE 54.—Heat coil.

grounds the line. The Western Electric heat coil has a resistance of about 3½ ohms and operates on ½ ampere in less than 3½ minutes. Figure 54 shows a diagram of that coil (with the shell cut away) and the springs between which it is mounted. The coil is mounted as shown between springs *a* and *b*, *b* is held rigidly while *a* exerts a pressure on the coil at all times in the direction of *b*. When the coil operates the pressure of *a* forces the core to move through the collar, pushing spring *c* against ground and thereby grounding the line. Thus, low potential current which might have gone through central office equipment and injured it has been provided with a direct path to ground.

b. Self-soldering type.—There is another type heat coil known as the "self-soldering" type. It derives this name from the fact that upon cooling after operation, it resolders itself so as to be again usable by a mere change of position in the protector mounting.

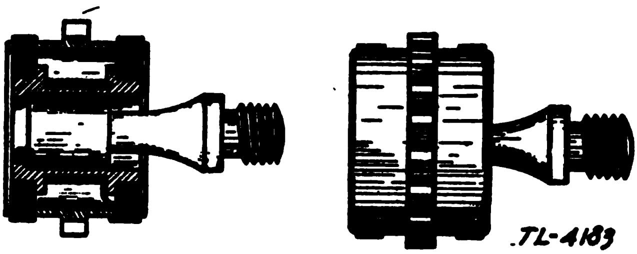

FIGURE 55.—Cook self-soldering heat coil.

The most widely used coil of this type is shown in figure 55. The coil is provided with a ratchet on its outer edge, one of the teeth of which serves as a detent for the movable arrestor spring as long as the coil is prevented from rotating by the solder. When, however, the solder is melted, the ratchet is allowed to turn thus

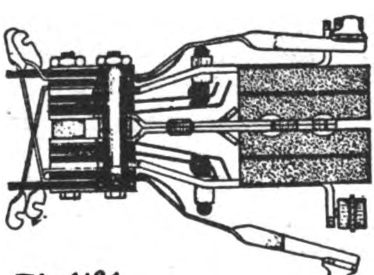

FIGURE 56.—Cook central-office protector.

releasing the spring. These protectors are reset by merely placing the controlling spring in engagament with another tooth of the coil after the solder has again hardened.

As shown in figure 56 the protector on top is in its normal position, the ratchet on the heat coil holding the long movable spring in its flexed position. When so held, the circuit from the outside to the inside line wire is completed through the heat coil. Also, by means of the insulating plunger engaged by the mid portion of the movable spring, the two short inner springs are held out of engagement with the line spring.

The lower side of the protector in figure 56 is shown in the operated position. The solder has melted to the point where the ratchet has turned and released the long outer spring, thus opening the line circuit. Also by releasing the pressure on the insulating plunger, the two shorter springs are allowed to engage the spring forming the terminal of the outside line. The inner one of these short springs is seen to be in permanent connection with the ground plate and it thus serves to ground the outside line. The other one of the short springs also becomes grounded by engaging the now grounded line spring. It forms the terminal of an alarm circuit, which is thus energized to sound an alarm whenever any heat coil operates. This heat coil will operate in less than 210 seconds on 0.5 amperes and will carry 0.35 ampere for 3 hours with a room temperature of 68° F. As heat coils are used in conjunction with open space cutouts in the central office, their location and the way in which they fit into the circuits will be shown later.

50. Fuses.—When a telephone conductor is grounded by the operation of a protector, current will continue to flow through the telephone conductor to ground as long as the exposure continues. The current may be large enough to damage the telephone conductor or the protective apparatus itself. Accordingly it is necessary to insert in the conductor on the line side of the protector, a device which opens the conductor when the current is too large. Fuses are used for this purpose. Fuses designed for protection of telephone lines are tubular shells about 4 inches long inclosing a fusible wire of from 1 to 7 amperes capacity. Heat coils, of course, will function on the heavier currents resulting from high potential (class 3), but as pointed out above this does not open the circuit so that this heavier current may damage the cable unless a fuse is provided to open the circuit. The capacity of fuses is relatively high to prevent

burn-outs on currents from low potentials which are insufficient to damage the cable and other material. In this case, the heat coil only will operate and prevent the current from reaching the switchboard. Fuses are provided at the central office for all wires entering from aerial cable or open wire but not for underground cable. In the latter case, it was formerly the practice to install fuses at the point where aerial plant went underground. Now it is common to use a section of smaller gage cable such as #24 or #26 at this point, which accomplishes the same result as if fuses were used.

51. **Lightning arrestors or open space cut-outs.**—Open space cut-outs are designed to protect against lightning or other extra high potential by affording a path for it to arc to ground. Figure 57 shows a standard arrestor in use today. The upper block is of porcelain. Imbedded in it and held in place by glass cement is a small rectangular block of carbon. The lower block is a solid piece of carbon. When mounted in the protector as shown in figure 57 there is a small air gap between the two carbon blocks. The right hand drawing of figure 57 gives a cross section through the two blocks and clearly shows this air gap. This gap forms the protection against high potentials existing between a line and ground. A lightning discharge across the gap will not usually cause a permanent grounding of the line, but, if a high potential exists long enough to maintain an arc for an appreciable length of time, the heat created will cause the glass cement to melt and allow the protector spring to

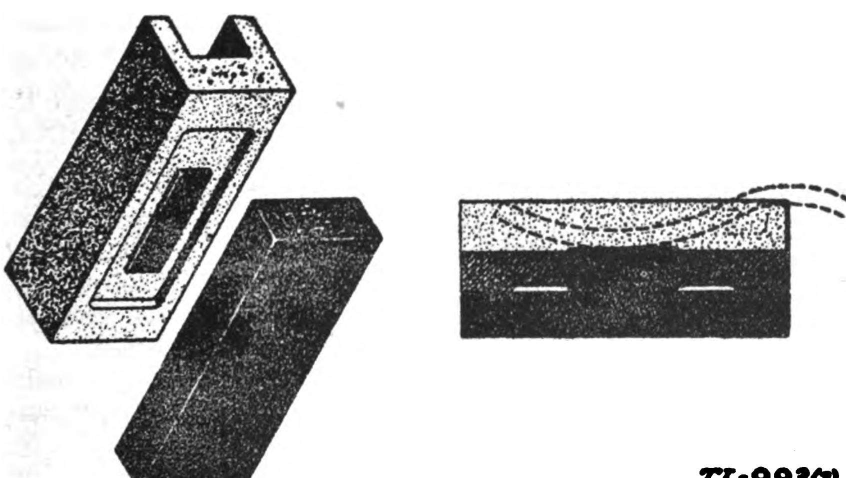

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FIGURE 57.—Open space cut-out.

force the smaller carbon block against the larger one. This will create a permanent ground.

The air gap space between the blocks is designed so that the operating voltage of the protector will be less than the break down voltage of the weakest point of the circuit which it is designed to protect and greater than the maximum working voltage of the circuit. The average operating voltage of the open-space cut-outs used at subscriber stations and in central offices is about 350 volts.

The older type of lightning arrestor consisted of two rectangular carbon blocks separated by one thickness of U-shaped mica. The inner face of the grounded block has a fusible metal slug imbedded in it. An arcing current melts this slug and causes it to form a permanent path to ground. When mounted, the gap in the mica should be downward to prevent dust collecting in the gap between the carbons.

52. Protectors.—Lightning arresters and heat coils are used together in a central office and the two combined are ordinarily called a protector. This protector is ordinarily referred to as a high potential sneak current protector. This is the protective device that was mentioned in the section on distributing frames. These protectors are in strips of 20 and are mounted on the vertical side of the frame. As will be remembered there are two types of frames, A and B. The protectors for these two types differ slightly in their construction only. Figure 58 shows a B frame protector. A is a heavy metal center piece by means of which the protector is connected to the distributing frame and thus to ground. The outside pair (which is connected to the protector in a type B frame), is connected to B and E. The jumpers connect to C and D which are brought out on the same side of the center piece. The jumper is never split. This is always true whether the frame is of the A or B type. It should be noted that when the protector is used in line circuits, as in the case of conductors entering a central office, the heat coil is mounted on the office side of the open-space cut-out. In this position the heat coil wiring aids the operation of the open-space cut-out by presenting a considerable impedance to suddenly applied voltages such as are produced by lightning discharges.

The only difference between the A frame protector and figure 58 is in the arrangement of the spring assembly. The switchboard pairs connect to the protector in this case and are split, but the jumper is not. At the same time, the heat coils must be on the unexposed side of the arrestors.

53. Switchboard fuses.—*a.* In addition to the protection afforded the switchboard apparatus from outside hazards, it is also protected from damage from its own battery current. This protection is pro-

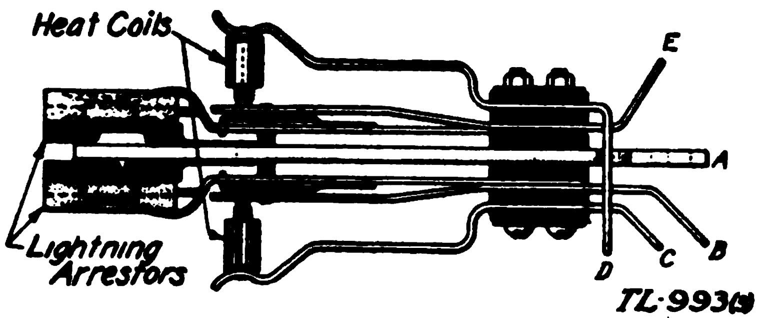

FIGURE 58.—Western Electric Co. central-office protector.

vided by small fuses in each group of circuits. In a large central office there are hundreds of these fuses. For continuity of service it is necessary for the office maintenance force to know the instant a fuse blows and to be able to locate it quickly. For this reason, indicating fuses, as shown in figure 59, are used. As shown, the fuse is mounted outside between the battery bus and the stud on which the circuit (or group of circuits) fused by it terminates; and between these mountings is a thin bus bar which connects to ground through a pilot light and alarm bell. When any fuse blows both springs are released. The coil spring throws the glass bead out of line so that it can easily be seen and the flat spring makes contact

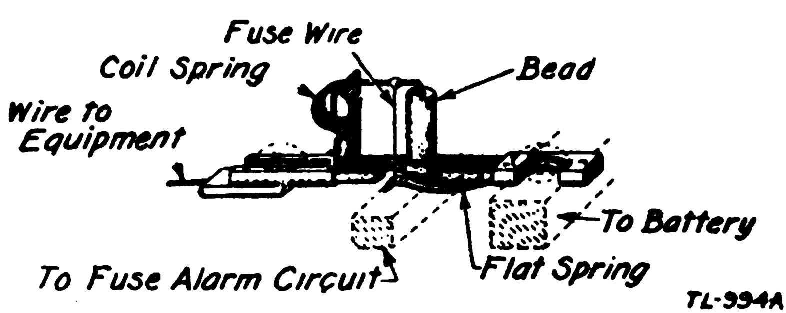

FIGURE 59.—Western Electric Co. 35-type alarm fuse.

with the fuse alarm bus, putting battery on that circuit. The ringing of the bell calls the attention of the attendant and the particular pilot lamp burning shows him on which panel the blown fuse is

located. By inspection of the panel for a fuse with the bead raised out of line the particular fuse is located. It is usual to replace one fuse without investigating the cause of failure, but if the second fuse blows out the cause of the trouble is searched out and cleared.

b. Fuse sizes.—Switchboard fuses are avilable in various sizes of which ½, 1-⅛, 2, and 3 ampere capacities are most common. The fuse circuit prints will show which size to install in each case, and when replacing fuses the capacity of the fuse removed will show the size to use for replacement. To aid in the identification of the fuses and particularly to prevent a fuse of the wrong rating being used in a given place, the glass beads are variously colored. If the proper size of fuse is not available, use a piece of fuse wire of proper size. Never use copper wire in place of a fuse, and never replace a fuse with another of larger capacity.

54. Acoustic shock reducer.—There is another piece of protective equipment found in the switchboard. This is a varistor-type acoustic shock reducer that is used in the operator's circuit. In use, the varistor is bridged on the receiver branch of the operator's telephone set, usually being wired across the receiver leads at the telephone jacks in the switchboard.

When the varistor has applied to it the relatively low voltages due to speech at ordinary levels its impedance is high (about 30,000 ohms at 0.1 volt) and it shunts from the receiver only a small amount of current. When relatively high voltages are impressed on the operator's telephone circuit the impedance of the varistor drops to a low value (about 15 ohms at 1.5 volts) and causes most of the current to be shunted from the receiver, thereby greatly reducing the intensity of acoustic disturbances.

55. Questions for self-examination.—

1. What is meant by a hazard?

2. Name three types of hazards to which the telephone plant is exposed.

3. What is a heat coil?

4. Against what type of hazard does a heat coil protect?

5. Draw a schematic diagram of a heat coil, showing the circuit through it.

6. Do all heat coils open the circuit when they operate?

7. What is a fuse?

8. Against what type hazard does a fuse protect?

9. Why is it necessary to have both fuses and heat coils in the same circuit?

10. Is underground cable fused as it is brought in to the central office? Why?

11. What is an open space cut-out?

12. Against what type hazard does an open space cut-out protect?

13. What type open space cut-out is generally used in the army exchanges?

14. Describe the older type cut-out containing the two carbon blocks.

15. What two protective devices are combined and called a central office "protector"?

16. Where is this protector mounted?

17. Upon which side of the open space cut-out should the heat coil be in this protector? Why?

18. Are the protectors used on A and B type frames identical? Why?

19. What type of fuse is used to protect central office equipment from the central office battery?

20. Why is this type of fuse used?

21. What is the purpose of the "acoustic shock reducer?"

22. Describe the operation of this acoustic shock reducer.

SECTION VII

NOISE, CROSSTALK AND TRANSPOSITIONS

56. General.—An important factor upon which the intelligibility of a telephone conversation depends is the absence of excessive noise and crosstalk. It is not only necessary to keep the attenuation or loss on the line within certain limits but noise and crosstalk should be reduced to a minimum. This requires what is known as a high degree of line balance, involving the use of transpositions, and other means of preventing a transfer of energy from so-called disturbing circuits (i.e. power circuits, other communication circuits) to disturbed circuits. In general terms, crosstalk is the transfer of energy from another communication circuit, and noise is the transfer of energy from a power circuit or other source. If crosstalk comes from several other communication circuits at the same time the results may be considered to be noise, or what is frequently called babble. Since the fundamental explanation for the causes of crosstalk is the same as for noise, a discussion of the former will be given in more detail in this section.

57. Crosstalk.—In explaining the reason for crosstalk, let us assume typical open wire, long distance lines, and see how conversation over one pair of wires may be heard in another if the lines are not properly balanced.

a. Magnetic induction.—Referring to figure 60, we will assume that an alternating current with its source at the left end is flowing in the circuit made up of wires *1* and *2*. Assume further that the current is flowing for the instant in the direction indicated by the arrows in figure 61, which represents the same circuit as figure 60. We know that a current flowing through a wire sets up a magnetic

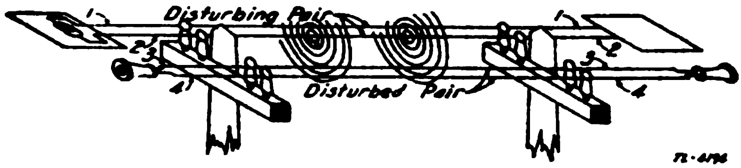

FIGURE 60.—Crosstalk-magnetic induction.

field or lines of force about itself in circular form and perpendicular to the wire. This field set up about wire *2*, expanding and contracting with the rise and fall of the current in the wire, cuts wires *3* and *4*. More lines of the field cut conductor *3* than cut conductor *4*, because the former is nearer the disturbing wire. Due to magnetic induction, wires *3* and *4* will have voltages induced in them. This effect may be likened to an infinite number of tiny alternating current generators, each in series with the line, those in wire *3* producing a slightly higher voltage than the ones in wire *4*. This is illustrated in figure 61. In figure 61 let us designate the sum of

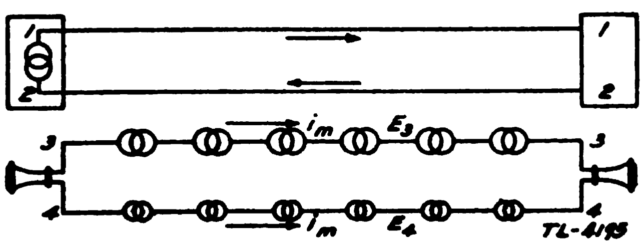

FIGURE 61.—Crosstalk-equivalent magnetic circuit.

all the voltages induced in wire *3* as E_3 and in wire *4* as E_4. Assuming the same number of tiny generators in both wires *3* and *4*, it is evident that E_3 is somewhat greater than E_4. Since these voltages are induced from the same magnetic fields, they are all in the same direction and consequently oppose each other when considered around the loop circuit composed of wires *3* and *4*. Thus we have a resultant voltage operating in the loop equal to $E_3 - E_4$. This voltage will cause an alternating current to flow through the receivers at both ends and it will follow the alternations of the current in wire *2*. If the parallel exposure with the disturbing circuit is long enough we can hear distinctly in the receivers on wires *3* and *4* any conversation being carried on over wires *1* and *2*.

Wire *1* of figure 61 also sets up a resultant voltage in wires *3* and *4* just like wire *2* did, but the voltage will be in the opposite direction because the current in wire *1* is opposite to that in wire *2*. Also, since wire *1* is further away from the disturbed pair the resultant induced voltage is less so it is overcome by that set up by wire *2*.

b. Electro-static induction.—Alternating voltages as well as currents may be the source of crosstalk. In the case of the magnetic induction we say that the lines of force cutting the disturbed conductors produced the voltage causing crosstalk. Due to the electrostatic field around wire *2* there will be a voltage impressed upon wire *3* equal to E_{23} and upon wire *4* equal to E_{24}. The voltage on wire *3* will be greater than that on wire *4* because wire *3* is closer to wire *2*. Thus there will be a difference in potential between wires *3* and *4* equal to E_{34}. This can better be seen by reference to figure 62. Likewise, there will be a difference in potential between

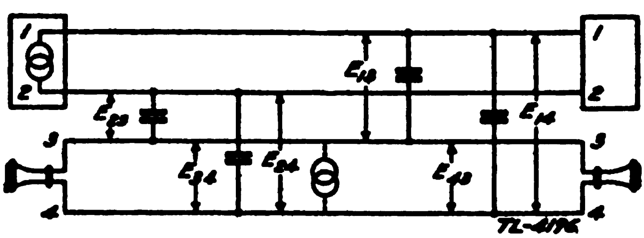

FIGURE 62.—Crosstalk-electro-static induction.

wires *3* and *4*, due to the electro-static field around wire *1*, equal to E_{43}. This latter voltage will be of exact opposite phase as that of E_{34} and will be smaller since wire *1* is further away from the disturbed pair than wire *2*. As far as the disturbed pair is concerned, it may be considered that a small a-c generator with a voltage equal to E_{34} minus E_{43} is connected across wires *3* and *4* as represented in figure 62. Here again if the exposure is long enough, understandable crosstalk will result in the disturbed pair.

c. Combined effect of magnetic and electro-static induction.—To summarize the effects of both magnetic and electro-static induction as causes of crosstalk, let us refer to figure 63. Hence the combined crosstalk effect may be thought of as tiny a-c generators in series and one small generator across the circuit of wires *3* and *4*. Under these conditons it can be seen that the currents from the two sources of crosstalk are additive in the left portion of the line

and subtractive in the right hand portion. In other words, the combined crosstalk effect of electro-static and magnetic induction is

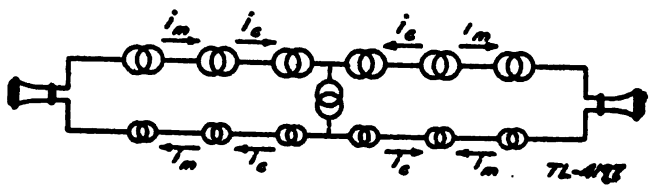

FIGURE 63.—Crosstalk-combined magnetic and electro-static induction.

additive in the case of near-end crosstalk and subtractive in the case of far-end crosstalk.

d. Resistance unbalance and crosstalk.—In addition to the two causes of crosstalk discussed in paragraphs *a* and *b* there is another fundamental consideration. It has been assumed up to this point in our discussion that the two pairs in figures 61 and 62 were electrically identical throughout their entire length; that is they have the same series resistance and size per unit length. This is generally true, particularly of cable, but for open wire there is always the possibility of bad joints, bad insulation, etc. When a circuit, say the disturbed pair in figure 61, is not electrically the same for each unit of length, the assumptions to be made later in this section in discussing transposition will not hold, and transposition loses part of its effect.

(1) *Phantom circuits.*—Phantom circuits are particularly susceptible to resistance unbalances, so they will be discussed here. Even with proper side circuit and phantom transpositions, objectional crosstalk may still exist due to resistance unbalance. Referring to figure 64, assume that there is more resistance in wire *1* than wire *2* of side circuit *1*. Wires *3* and *4* of side circuit *2* have the same resistance as wire *2*. Now assume further that an alternating current is introduced into the phantom circuit at the left end. The current in the phantom through side circuit *1* will divide in wires *1* and *2* inversely proportional to the impedance of these two wires. Since there is more resistance in wire *1* more current will flow in wire *2* than in wire *1*. Thus there is an unbalance in current through both repeating coils of side circuit *1* and crosstalk will result in this side circuit from the phantom. A similar analysis will show that side circuit *1* will crosstalk into the phantom.

58. Noise.—Assume that wires *1* and *2* of figure 60 are replaced by a commercial power circuit of high voltage and carrying alternating current of large magnitude as compared to that in the telephone circuit. Naturally this condition would induce voltages into

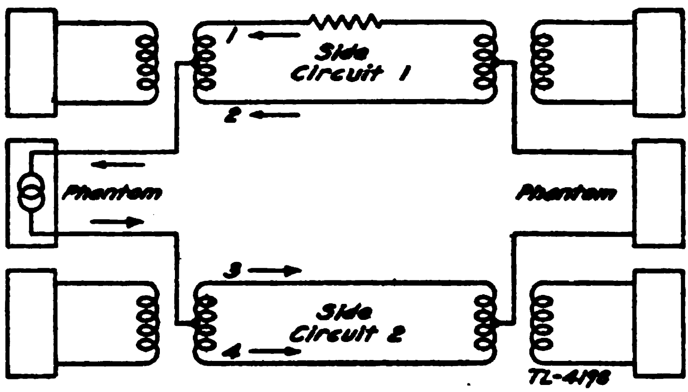

FIGURE 64.—Phantom crosstalk due to resistance unbalance.

lines *3* and *4* in the same manner that the telephone currents did. These induced voltages, however, would be much larger than those from the telephone currents. You can see the necessity of keeping the telephone circuit as far away as possible from all power circuits in order to avoid these so-called "noise effects."

59. Transposition, general.—*a.* Although there are several ways to reduce crosstalk, including symmetrical configuration of the disturbing and disturbed circuits, transposition is the most practical. Refer to figure 61. Transpose wires 3 and 4 at the center and consider the effect of magnetic induction. Figure 65 shows this change.

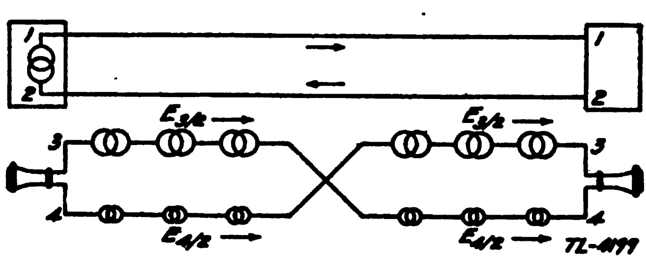

FIGURE 65.—Reduction of noise by transposition.

It is obvious that the resultant voltage effective around the loop circuit of the disturbed pair is

$$\frac{E_3}{2}+\frac{E_4}{2}-\frac{E_3}{2}-\frac{E_4}{2}$$

or zero. Thus there will be no crosstalk. Inspection will show that wires *1* and *2*, transposed in the same manner, would be just as effective. However, transposing both pairs in the center would be, in effect, the same as no transposition at all as far as balancing out crosstalk is concerned. A similar analogy holds for electro-static induction since the capacitance between the various wires and between wires and ground is balanced on either side of the transposition point. Thus it is seen that transposition reduces crosstalk from both electro-static and magnetic induction.

b. While a single transposition as discussed above is effective in reducing crosstalk in a short section, it will not suffice for too long a section. There are two principal reasons for this. First, because of attenuation, the current and voltage near the energized or so-called near end of a disturbing communication line is many times that at the far end. It would not be expected, therefore, that the induced crosstalk on the near-end side of the transposition would be neutralized by the weaker crosstalk on the far-end side of the same transposition point. As a mattery of fact, even in a short section, the transposition will not completely eliminate near-end crosstalk. The second reason why a single transposition is not effective in reducing crosstalk on too long a section is the change or shift of both current and voltage along the line at a given instant. Although the voice current in a line is considered as flowing in series throughout the line and thus for any particular instant bearing the same phase relationship with the transmitted current, this assumption can not be made for an electrically long line. Actually the magnitude of the current in the line at some instant might look like that shown in the curve of figure 66. Here it can be seen that

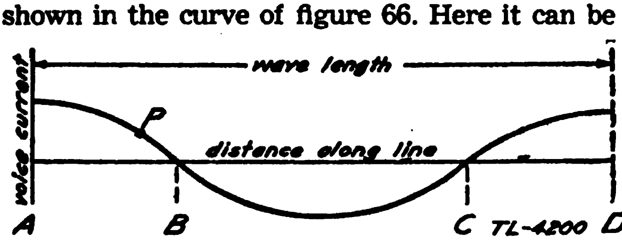

FIGURE 66.—Current cycle in disturbing circuit.

at points B and C the current is actually zero. This phenomenon must not be confused with the frequency of the voice currents being transmitted. It represents the instantaneous picture of current on the line between point A and D. The distance between A and D will be in the order of 175 miles for open wire and 8 to 50 miles for cable. Thus it can not be expected that crosstalk on both sides of a transposition, say at point P, will balance. It is necessary, accordingly, that transposition be installed at rather frequent intervals with respect to the so-called wave length or distance A–D in figure 66.

60. Transposition practices.—So far the discussion has considered only the simple condition with two parallel open wire circuits. It is obvious that a greater number of circuits in a group generally will be involved.

a. Open wire.—Physically there are two standard methods of effecting a transposition between wires of a pair on a pole line. These, known as "point-type" and "drop-bracket" transpositions, are shown respectively in figures 67 and 68. The "point type" is used extensively on carrier circuits because it does not change the configuration of the wires in adjacent spans. The "drop-bracket" type is generally used on voice frequency lines. As far as laying out the location and number of transpositions is concerned, there is

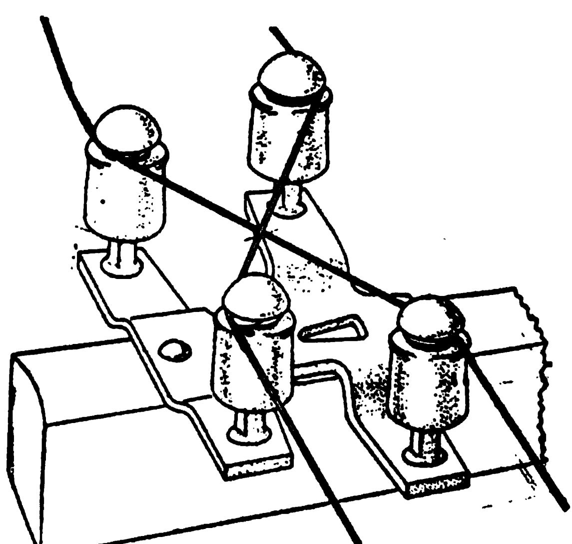

FIGURE 67.—Point-type transposition.

no hard and fast rule. The line is usually divided into sections in each of which complete crosstalk balance is approached as closely as possible. Thus any number of sections may be connected in tandem. Nonuniformity in length of individual sections may be re-

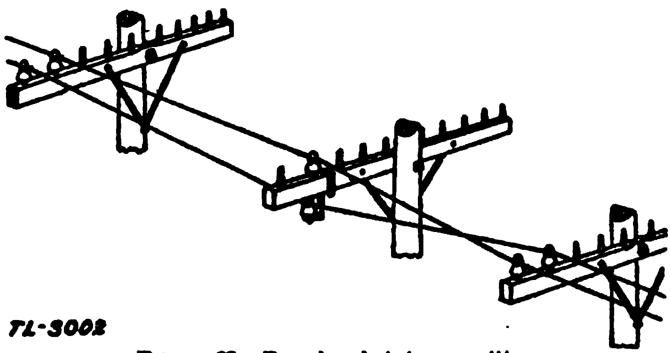

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FIGURE 68.—Drop-bracket transposition.

quired because of discontinuities in the line, such as junctions with other telephone lines, circuits added or dropped off and power line exposures. It is natural that such points of discontinuity should be made to coincide with the junction between transposition sections. Each section may have a number of transposition points, and their location is a matter of calculation for the individual section. For example, a section having a very bad power line exposure would have transpositions spaced much closer together than another section without the exposure. Sections may run from a few hundred feet to 6 or 8 miles.

b. Cable.—Long distance cable circuits, because of the close spacing of the pairs, must be transposed very often. This is done in the course of manufacture by twisting the two wires of a pair together, by twisting the two pairs of each group of four wires together to form so-called quads, and by spiralling the quads in opposite directions about the axis of the cable.

61. Questions for self-examination.—

1. What is noise in a telephone circuit?

2. What is crosstalk in a telephone circuit?

3. What are the two causes of noise and crosstalk, excluding resistance unbalance?

4. Would it be desirable if an open wire telephone line were properly transposed, to keep it away from power line exposures?

5. What are the two common types of physical transposition on pole lines?

6. Explain crosstalk as caused by:

a. Magnetic induction.

b. Electro-static induction.

7. Explain crosstalk as caused by resistance unbalance in a phantom side circuit.

8. How is cable transposed?

9. Give two reasons why a single transposition in a long telephone line would not be effective in reducing crosstalk.

10. Explain why properly spaced transpositions on a telephone circuit are effective in reducing crosstalk.

11. How are open wire lines usually broken up for the purpose of balancing out crosstalk and noise?

12. Will proper transposition reduce noise as well as crosstalk?

SECTION VIII

ATTENUATION AND LOADING

62. Attenuation.—*a. Definition.*—(1) It was brought out in section II that the energy of the sound waves produced by the voice moves the transmitter diaphragm of the telephone, thereby translating the mechanical energy into electrical energy. The telephone system is designed to transmit as much of this energy as possible from one telephone to another, regardless of whether the instruments connected are located in the same city or at opposite ends of the country. When the sound received at the receiving station is much lower in volume than the original spoken words, it is evident that some of the energy must have been lost in transmitting it from one point to the other. This loss of energy is commonly called transmission loss, and is made up of all the losses in the individual parts of the circuit. With a few exceptions, such as amplifiers, each piece of apparatus introduced into the talking circuit causes some transmission loss. In addition there is the loss in the line itself, which increases with the length of the line. The loss in the line is known as the attenuation loss or attenuation of the line.

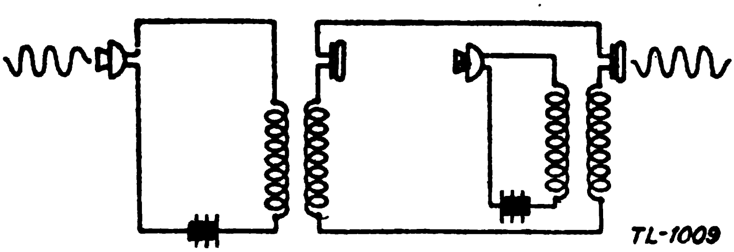

FIGURE 69.—Circuit with no line loss.

(2) If one telephone set is connected directly to another as shown in figure 69, the sound received will be slightly louder than the original words spoken into the transmitter since the transmitter itself is an amplifying device. The alternating current produced by the transmitting set flows directly to the receiving set, with nothing to impede it or shunt out any part of it. If, however, a length of cable, say 20 miles of 19-gage, is placed between the two instruments, the sound reproduced by the receiver will be much lower than that picked up by the transmitter at the originating end. This is illustrated in figure 70, where the difference in height of the sound waves indicates that a considerable portion of the energy has been lost in traveling from the transmitter to the receiver. As

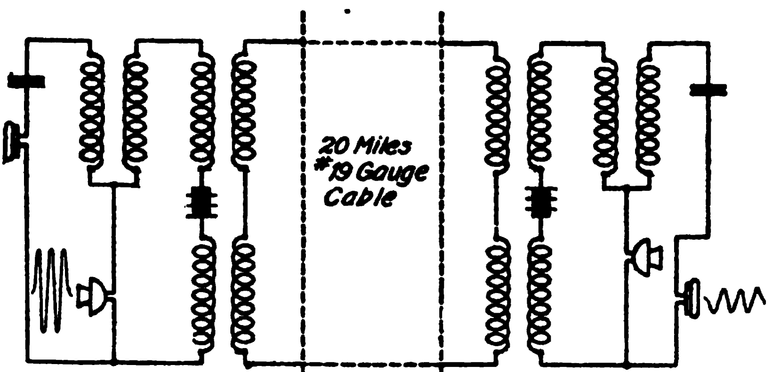

FIGURE 70.—Circuit with line loss.

shown, there is no apparatus in the circuit between the two repeating coils and this loss must, therefore, be due primarily to the attenuation of the line itself.

b. Characteristics of the telephone line.—(1) The energy is transferred from one end of the line to the other by means of alternating current and every line has certain properties or characteristics which affect this current. There is, of course, the resistance R of the conductors and also a small amount of inductance L causing some inductive reactance. Also, there is a distributed shunt capacitance C between the wires of a pair, and between the wires and other circuits and ground. In addition, all circuits have a certain escape of current or leakage, these leaks become larger as the insulation becomes poorer. This loss or leakage is ordinarily very low on cable circuits, but on open wire circuits, especially in rainy weather, it may be quite high.

(2) The various properties of a telephone line just referred to may be illustrated as in the diagram of figure 71. The diagram shows the distributed series resistance and inductance and the distributed capacitance and insulation resistance in parallel across the line. Attenuation in a telephone line may be defined as the progressive loss along a telephone line due to the combined effect of resistance, inductance, capacitance and leakage.

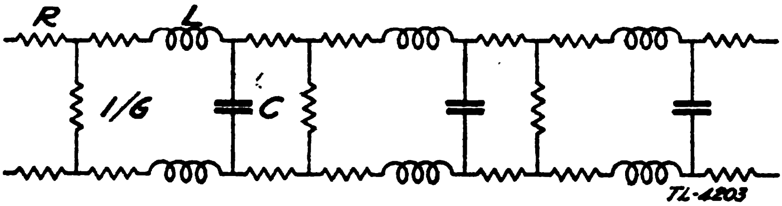

FIGURE 71.—Distributed line constants.

c. *Effect of line characteristics on attenuation.*—(1) The loss of the transmitted voice current between two telephone stations is due primarily to the attenuation in the line itself. If a circuit of any given type is long enough, it is naturally expected that the loss will tend to become so great that the energy reaching the distant end will be insufficient to operate the telephone receiver. It is to be expected in long transmission circuits that the resistance of the cable or line will consume a large percent of the power delivered by the transmitter, and the current through the leakage resistance will be lost. In cable circuits and long open wire lines the line capacitance is considerable, and accounts for a large portion of the loss incurred on the line. However, while transmission of the required volume is essential, it is not the only consideration. The loss due to this distributed capacitance is not equal for all frequencies, and this fact can readily be seen if you consider that the reactance of a capacitor varies inversely with the frequency: that is

$$X_C = \frac{1}{2\pi f C} \qquad (1)$$

Where X_C=capacitive reactance in ohms, f=frequency in cycles per second, C=circuit capacitance. Since the distributed capacitance has a shunting effect upon alternating current, it is evident from this equation that there will be a greater loss to currents of higher frequencies than the lower frequencies. An increase in f decreases X_C. Figure 72 illustrates the manner in which the attenuaation varies with frequency in cable circuits.

(2) The wave shape of voice currents is of a very complex nature and it can be proven that regardless of its complexity, the wave can be broken down into a number of sine waves. As these various frequencies are attenuated unequally, the shape of the received wave at the distant station will be materially changed so that

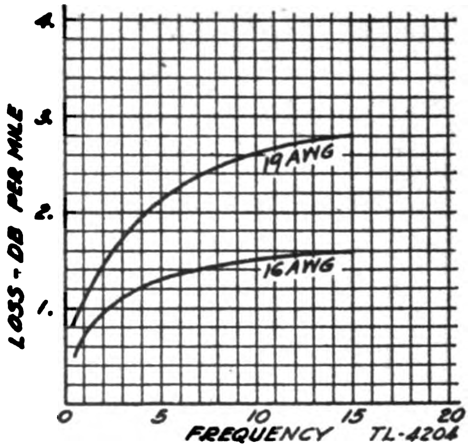

FIGURE 72.—Attenuation of cable circuits.

it will not produce the same sound in the receiver as that which was spoken into the transmitter. The effect of this unequal attenuation of the various frequencies making up the voice current is distortion, and can become serious enough to make the received signal unintelligible.

(3) There is also some inductance inherent in parallel conductors which decreases as the distance between conductors decreases. In cable the distributed inductance is negligible and that of open wire lines is very small. The effect of inductance is opposite to that of the capacitance and tends to neutralize to a degree the effect of the capacitance. This is explained under **Loading**, in paragraph 63.

d. *Manner in which energy in line is attenuated.*—The manner in which the energy in a line is attenuated can best be shown by a diagram. Consider the 20 miles of 19-gage cable shown in figure 70. The values of *R*, *L*, *C*, and *G* for a mile of this could be found from a table, or measured. From these values the attenuation constant could be calculated for some definite frequency. The amount of energy at any point in the circuit could then be found, assuming the energy delivered to the line as 100 percent. The results could

then be plotted as shown in figure 73. The diagram shows that the attenuation does not increase in a straight line relation with the length, but that the curve is logarithmic.

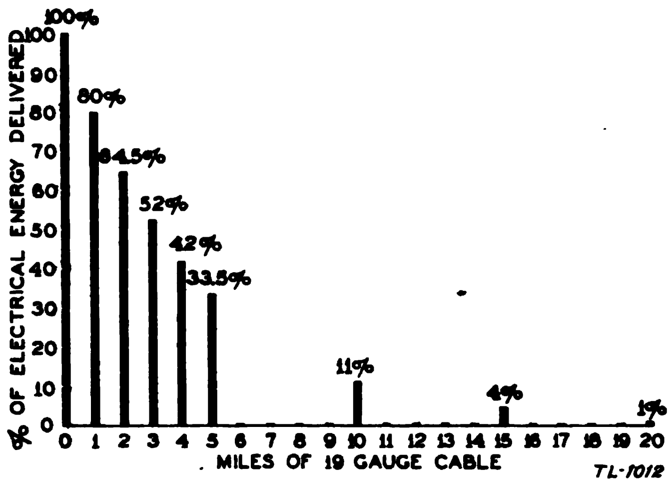

FIGURE 73.—Attenuation chart, 19-gage cable.

This curve drops off sharply in the first few miles (in fact 20 percent is lost in the first mile), and continues the same percentage drop for each mile of cable. That is, the energy leaving any one mile section of cable is always a definite percentage of the energy entering the other end of the same mile section. Thus, at the end of the first mile there remains 80 percent of the total energy. At the end of the second mile there is 64.5 percent of the total or approximately 80 percent of the energy that entered the second mile. The percentage factor varies, of course, with different types and sizes of conductor and with the insulation between conductors.

e. Means of reducing attenuation.—When the wire facilities are extended beyond the satisfactory transmission range there are several ways the attenuation may be reduced. Attenuation can be reduced by increasing the size of the conductor so that the series resistance is decreased, or by further separation of the conductors to reduce capacitance, or by reducing the line leakage with improved insulation, but beyond a certain point there are economic and physical limitations that make this impractical. The two most commonly used methods to increase the transmission range are loading and use of amplifiers.

63. Loading.—*a. Definition.*—By loading is meant the insertion of series inductance in a circuit to neutralize partially the effect of the distributed capacitance of the line or cable.

b. Purpose.—Loading has a two-fold purpose. It reduces line attenuation and reduces distortion caused by unequal attenuation of the harmonics of the voice current. The latter is of primary importance since the development of voice repeaters. Also, a more constant characteristic impedance for the frequencies within the band to be transmitted is obtained by loading.

c. Theory of loading.—(1) The theory of loading is by no means simple, and it is not in the scope of this text to make a mathematical analysis of loading. However, the subject can be covered by giving the general principles of loading so that it can be understood by anyone having a knowledge of alternating currents.

(2) It may be stated that loading corrects the phase angle, enabling us to obtain the advantage of a lower current transmission system, resulting in less line loss. In power systems, the effect of distributed line capacitance and inductance is not serious at 60-cycles, and usually the length of the line is a small fraction of a wave length. Therefore, the input impedance of the line is largely determined by the terminating impedance. In the power system the problem is relatively simple, as the reactance causing the voltage and current to be out of phase is at the termination, and can be corrected for by introducing a lumped reactance that will cause the current to be out of phase by the same angle as that caused by the load, but of the opposite sign. In a communication line the frequencies are higher, and the distributed capacitance of the line is large as compared with the distributed inductance. The length (in wave lengths) is also much greater. Under these conditions the input impedance is largely determined by the constants of the line, rather than its termination. The capacitive reactance of the line causes the current to lead the voltage, resulting in less power delivered to the receiving end.

(3) By inserting series inductance in the circuit, the phase angle is reduced, since inductive reactance will cause the current to lag the voltage. This tends to neutralize the effect of the capacitive reactance. Unfortunately, it is not possible to increase the inductance without increasing the resistance, due to the wire used in winding the coils, so that a balance between the inductive and capacitive reactance is approached only at the expense of adding

more resistance to the circuit. When loading, a point will be reached where adding more loading coils will not continue to produce an economic gain in transmission.

(4) Since the capacitance of the circuit is distributed over the entire length of the line, the problem of loading a telephone circuit is made more difficult than where the constants are lumped, as in power systems. It is possible to increase the inductance uniformily along a line by wrapping it with a tape of some ferrous material, such as permalloy. This treatment, called continuous loading, is expensive, and the amount of inductance which can be economically provided is small. Such loading is, at present, used only on submarine cable, where the difficulty of adding lumped loading is great.

(5) In practice a solution is effected by supplying the loading inductance in the form of coils inserted in the circuit at regularly spaced intervals. The addition of inductance in "lumps" will produce the effect of increasing the distributed inductance provided that the "lumps" are sufficiently close together. Thus it is that a loaded circuit usually has loading coils, which are nothing more or less than "lumps" of inductance, inserted at periodic intervals along the circuit, the interval depending upon a number of factors but always small enough to obtain the effect of distributed inductance with its accompanying reduction in attenuation. A circuit with "lumped" loading has the disadvantage of rapidly increasing attenuation when the frequency exceeds a certain value due to the fact that a series of "lumped" inductance and capacitance constitutes a low-pass filter.

d. Problems of loading.—There is a great deal to be said about the proper use, installation and maintenance of loading coils which cannot be covered here but will be found in the standard instructions. A few considerations are important however. On circuits using telephone repeaters the loading coils should be properly spaced and coils of the proper size used if the best results are to be obtained. The loading coil, C–114, used in the army is built into a case having terminals so arranged that there can be no error made in the connections to the line, but where the coils are to be connected into a cable circuit and are of the type where the four leads for each coil are brought out together, care must be taken to prevent a connection causing a reversal of one winding thereby neutralizing the coil's inductance. It is possible to place loading in

the two side circuits without loading the phantom circuit, and it is also possible by proper connection of the windings and by having the four windings of each wire of the phantom group wound on the same core, to load the phantom circuit without loading the side circuits. The connections are so made that the inductance cancels out as far as each side circuit is concerned, but is additive for the phantom circuit. One side circuit should not be loaded when the other side circuit is not loaded. The value of loading may be seen from the fact that a 19-gage side circuit if not loaded has an attenuation of slightly more than one db per mile and the line impedance has reactance to the extent that its angle is almost minus 43°. The same circuit loaded every 6,000 feet with load coils having 245 millihenries of inductance now has only a fourth as much attenuation and the impedance angle is reduced to slightly more than 2°. Loading the phantom with 155 millihenries every 6,000 feet improves the phantom circuit in the same manner.

64. The transmission measuring unit.—*a. The mile of standard cable as a unit of measure.*—It was realized early that some method of determining the transmission loss of a telephone circuit would be necessary if satisfactory service was to be given. In order to measure anything it is first necessary to have a standard unit of measurement. With this idea in mind the telephone people years ago selected one mile of the type of 19-gage cable first manufactured as the standard unit of measurement. This cable had a capacity of .054 microfarad and a resistance of 88 ohms per circuit mile. One mile of a cable of this type was known as a mile of standard cable. In order to determine the transmission loss of any circuit, two observers would talk over the circuit and then over a variable length of standard cable. When the standard cable was varied until the same volume of sound was obtained over it as over the circuit to be measured, the number of miles of standard cable was taken as the loss or transmission equivalent of the circuit. For example, if 18 miles of standard cable gave the same transmission as the tested circuit, the circuit was said to have a transmission equivalent of 18 miles.

b. The transmission unit or decibel.—(1) You have seen that the energy leaving any one mile section of a long circuit is a definite proportion of the energy entering that same mile section. This is true of sections of standard cable but this unit of measurement has the big disadvantage that the ratio of energy leaving a mile section

to the energy entering a mile section is not the same at all frequencies. This situation led to the dropping of the mile of standard cable as a unit of measurement and the substitution of an arbitrarily selected unit not differing greatly in magnitude from the standard cable mile through the voice range, but having exactly the same significance at any frequency. That is to say, this new unit represents always a fixed percentage reduction in power no matter what frequency is involved.

(2) For several years this new unit went without a name and was called the transmission unit or *TU*. Now the transmission unit or *TU* has been given a name, the "decibel," abbreviated to *db*. The number of *db* is 10 times the common logarithm of the power ratio, or

$$N_{db}=10 \log_{10} \frac{P_1}{P_2} \qquad (2)$$

where P_1 is the input power or energy entering the circuit and P_2 is the output. Thus, where a circuit has a transmission loss of 1 *db* at a certain frequency, the ratio of input power to output power is 1.25. The *db* is also the unit of amplification or transmission gain as well as loss and in such case P_1 in equation (2) would be the output power and P_2, the input.

(3) When referred to some arbitrary level, the decibel is often used as a unit of absolute value of power, e.g., in telephone testing the zero level is 1 milliwatt of power across a 600-ohm load and other powers are referred to it. When not otherwise specified, the reference level is 1 milliwatt into a 600-ohm impedance at a frequency of 1000 cycles, the average of voice frequencies.

(4) While the decibel is primarily a unit of power ratio, it is apparent that if the receiving end impedance is constant and equal to the output impedance, equation (2) may also be written

$$N_{db}=10 \log_{10} \frac{I_1^2 Z}{I_2^2 Z}=20 \log_{10} \frac{I_1}{I_2} \qquad (3)$$

where I_1 and I_2 are input and output currents respectively, or

$$N_{db}=20 \log_{10} \frac{E_1}{E_2} \qquad (4)$$

where E_1 and E_2 are input and output voltages respectively.

65. Questions for self-examination.—

1. What is attenuation?

2. What are the distributed characteristics of a telephone line?

3. How do these characteristics affect attenuation?

4. What effect other than attenuation do these line characteristics have upon voice currents?

5. Explain how the voice currents are distorted in long transmission lines.

6. In what manner is energy in the line attenuated?

7. What are the practical methods of increasing the transmission range of a circuit?

8. What are loading coils?

9. How are they connected in a line?

10. Explain how loading coils reduce the line attenuation.

11. In a phantom group, is it possible to load the phantom without loading the side circuits?

12. Is it possible to load the side circuits without loading the phantom?

13. Should one side circuit be loaded without loading the other?

14. What is meant by continuous loading?

15. What is the decibel?

16. When the current ratio rather than the power ratio is known, what must be true of the input and output impedances to satisfy equation (3)?

17. If the input power is .001 watts and the output power is .00001 watts, what is the loss expressed in db?

SECTION IX

TELEPHONE REPEATERS

66. General.—*a. Need for repeaters.*—Even with the most efficient circuits and the standardized practices of loading there are limitations to the distance over which satisfactory telephone communication can be obtained. Where the circuit net losses are greater than 30 db, the attenuation is so great that conversation is barely possible. The loss over a 104-mil copper circuit 1000 miles long is approximately 70 db. In terms of power this means that if the input to such a circuit were 1 milliwatt, the power received at the distant end would be 10^{-10} watts or 1/10,000,000 of a milliwatt. It is evident from these figures that some amplifying device to boost the transmitted power along must be used in very long circuits.

b. Definition.—Such a device to maintain the energy of the signal is the voice repeater. The voice repeater is simply an amplifying device. It performs the same function in telephone circuits that telegraph repeaters perform in telegraph circuits. In fact the first telephone repeaters were mechanical, following more or less the idea involved in the design of the telegraph repeater. With the development of the vacuum tube, and the subsequent development of the vacuum tube repeater, the use of the mechanical repeater was discontinued.

c. Spacing of repeaters.—An important consideration in all communication systems is the signal-to-noise ratio. As there are always small amounts of energy picked up by any circuit, it is necessary to keep the strength of the signal much greater than that of the

noise. When the strength of the signal falls so low that the signal-to-noise ratio is small and then is amplified, the strength of the noise current as well as the strength of the signal current is increased. If this signal is again attenuated to an energy level comparable to the noise level, then the signal-to-noise ratio drops further and the intelligibility of the signal suffers. The signal-to-noise ratio is kept high by using several repeaters with small gain rather than one repeater with a large gain.

In practice it has been found that in most cases the repeater spacing, on open wire 104-mil copper, should not exceed 150 miles, and the average spacing of repeaters on cable circuits is approximately 50 miles.

d. Levels.—In telephone circuits employing voice repeaters the energy level at various points along the circuit is often referred to, and a knowledge of the actual values of these levels is of utmost importance in spacing and adjusting repeaters. Since gains and losses are expressed in decibels, it is convenient to express energy levels in the same unit. However, since energy levels are a definite value and not a ratio, the decibel, when used to express energy levels must express a definite unit of power. In order to make the decibel express an absolute unit of power, an arbitrary value is taken as a reference level to which all other powers are compared. In telephone testing, the zero level or reference point is 1 milliwatt, which is the approximate average output power of a telephone transmitter. All other energy levels are expressed as plus or minus a certain number of decibels depending upon whether the power level is above or below 1 milliwatt. This is illustrated graphically in figure 74. The input at point *A* is 1 milliwatt. The curve repre-

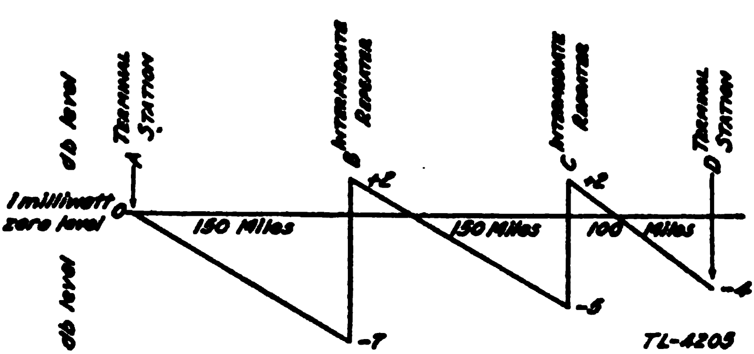

FIGURE 74.—Energy level diagram.

sents the energy level at all points along the circuit referred to the output power at *A*. Between points *A* and *B* the attenuation of the line reduces the energy, and the input at *B* is referred to as being 7 db below zero level, or simply as a minus 7 db. The repeater at *B*, having a gain of 9 db, amplifies the signal and raises the output power at that point above the level of the input power by 2 db, and is referred to as plus 2 db level. Between *B* and *C* the line again attenuates the signal. At the input to point *C* the signal level is minus 5 db. The gain of the repeater at *C* is 7 db, which brings the level from a minus 5 db back to a plus 2 db. The signal arrives at the distant terminal at a level of minus 4 db. By having a common unit for expressing levels, gains, and losses, these units may be added and subtracted algebraically, simplifying considerably the testing of such circuits.

e. Amplification of alternating currents—vacuum tubes.—Since the vacuum tube amplifier is an essential part of a repeater an understanding of the amplification process is desirable.

(1) *Two-element tube.*—The simplest form of vacuum tube is the two element tube consisting of a cathode and an anode (plate) enclosed in a glass or metal shell from which the air is exhausted. Figure 75 shows a two element tube. The cathode is the source from which electrons or negatively charged particles are emitted when the cathode is heated. This emission of electrons forms an electron

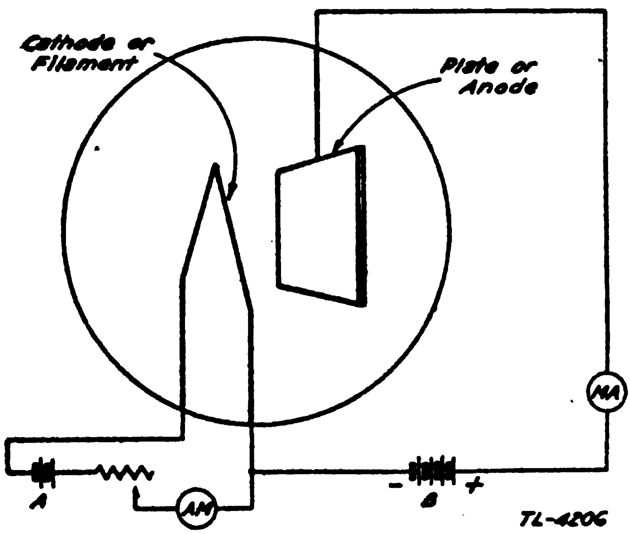

FIGURE 75.—Two-element vacuum tube.

cloud around the cathode called the "space charge." The function of the plate is to collect these charged particles. In order to make the plate collect these freed negative particles the plate is given a positive charge. A battery is connected between the cathode and the plate and is poled so as to give the plate a positive charge. This charge will exert a force of attraction on the electrons emitted from the cathode. Electrons escaping from the cathode will be drawn to the plate by the force set up by its positive charge and a continuous flow of electrons from cathode to plate will result. The electron flow through the ammeter is called the "plate current." The speed with which the electrons cross from the cathode to the plate is determined by the potential of the plate with respect to the cathode. However, a point of saturation will be reached where further increase in plate voltage will not increase the flow of electrons. This is illustrated in figure 76 where plate voltage is plotted against plate current.

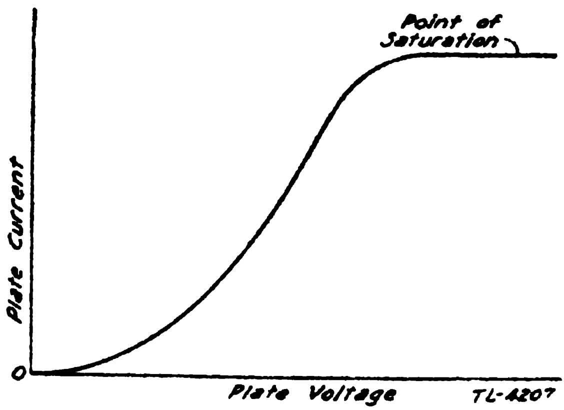

FIGURE 76—Plate voltage vs. plate current characteristic.

The flow of electrons between the cathode and plate is simply an electric current, and the *B* battery will sustain this current in the same way that a battery sustains a current when it is connected to any closed electrical circuit.

If the *B* battery is replaced by an alternator, current will flow only when the plate is positive, consequently the circuit acts as a valve passing current in one direction only. Such a circuit is called a rectifying circuit.

(2) *Three-element tube.*—By introducing a third element, the grid, in the tube the flow of electrons from the cathode to the plate may be controlled by varying the potential applied to the grid. Figure 77 shows the same tube as figure 75 with a grid added.

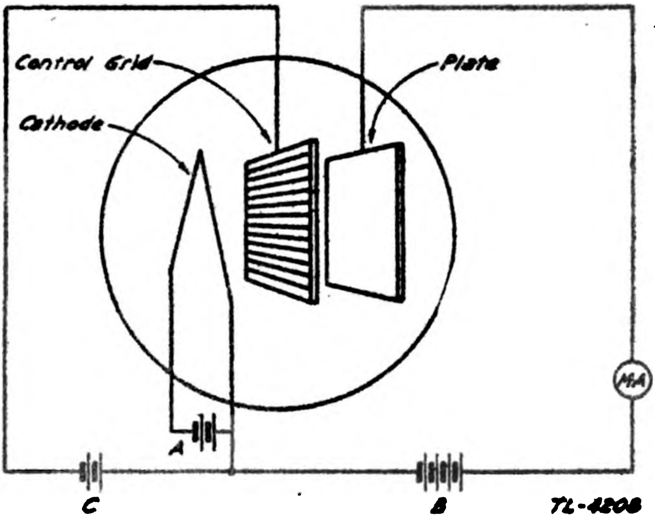

FIGURE 77.—Three-element vacuum tube.

The grid is usually in the form of an open spiral or mesh of fine wires and is inserted between the cathode and the plate. In this device the electrons which leave the cathode must pass through the meshes of the grid to reach the plate. Their passage is influenced by any force that may be set up by a charge on this grid. Since the force exerted by charged bodies varies as the square of the distance between these bodies, a small voltage applied to the grid would make a large change in the number of electrons leaving the cathode. This fact gives the three element tube its amplifying characteristic.

If the charge on the grid is negative with respect to the cathode, the electrons will be repelled by this negative charge and fewer electrons will reach the plate. If the voltage applied to the grid is large enough no electrons will pass to the plate. However, if the grid is made positive with respect to the cathode, more electrons will be drawn from the cathode. When they reach the grid, a few electrons collect there and cause current to flow in the grid circuit, but due to the velocity of the electrons most of them pass through the

wire mesh and are drawn to the higher charged plate. Thus, a negative grid decreases the plate current and a positive grid increases the plate current.

(3) *Simple amplifier.*—If an input transformer is added in the grid circuit and a load such as a telephone receiver in the output circuit, figure 77 becomes a simple amplifier. These additions are shown in figure 78. If an a-c signal is applied across the input coil, the grid will be made alternately more and less negative and cause

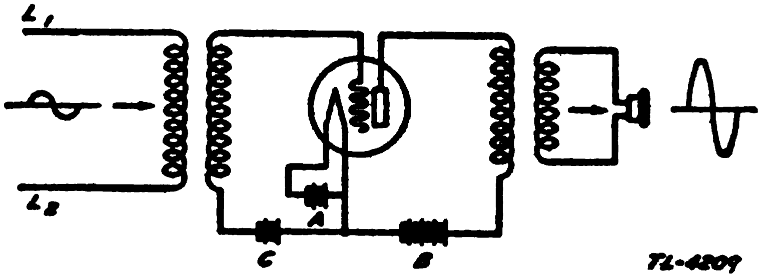

FIGURE 78.—Amplifying circuit.

the plate current to vary in accordance with the applied signal. This pulsating current in the plate will appear as alternating current in the secondary of the output transformer, causing the receiver to respond to the input signal. The output signal will be of a much greater magnitude than the input signal, due to the amplification of the tube.

(4) *Bias.*—In such a circuit where a minimum of distortion is desired it is very important that no current flow in the grid circuit. A positive grid collects some electrons and will cause distortion. This source of distortion is overcome by applying a negative grid bias (a fixed d-c voltage) to the grid so that the applied signal voltage will make the grid more or less negative about a mean point (operating point), but will never swing the grid positive. The grid voltage being made more or less negative will vary the plate current accordingly, but will not collect any electrons since it is always at a negative potential. This is shown in figure 79.

By using the proper grid bias, an operating point may be selected on the straight section or linear portion of the characteristic curve. At this point it is evident that the plate current wave shapes are identical reproductions of the grid voltage wave shapes and will remain so as long as the grid voltage amplitude does not reach values sufficient to run into the lower- or upper-bend regions of the curve. If this occurs the output waves will be flattened or distorted.

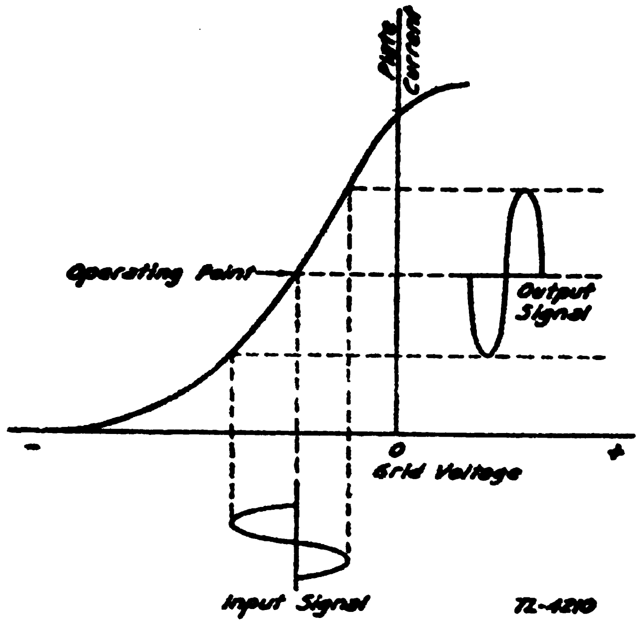

FIGURE 79.—Vacuum tube as amplifier.

If the grid is always at a negative potential, the circuit between the cathode and grid is substantially open to incoming signals. Therefore, since no power is dissipated in this circuit, the received signal need only be strong enough to supply the excitation losses in the input transformer. Thus, a very small amount of power can be used to control a relatively large flow of current in the plate circuit.

In this discussion of the amplifier only three-element tubes have been considered. Other types of tubes having four or five elements perform in a similar manner. The additional elements are refinements which give the tube better and more stable operating characteristics.

67. **Requirements of a repeater.**—*a.* There are various types of repeaters to meet the many different situations where amplifying devices are needed. The simplest form of a repeater is the one-way repeater. The requirement of this repeater is that it amplify the voice currents in one direction only. Such an arrangement is shown in figure 80. The only place where such a repeater is used ordinarily is on a circuit used for the transmission of programs between radio stations.

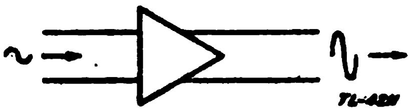

FIGURE 80.—One-way amplifier.

b. In communication systems where transmission is in both directions, a repeater necessarily has to be a two-way amplifying device. The first idea which occurs to the experimenter is to connect two amplifiers side-by-side as shown in figure 81, one to operate in one direction and the second to operate in the opposite direction. This arrangement will not work, however, because any energy amplified in one circuit is connected to the input of the other, to be again amplified and returned to the first. This returning energy

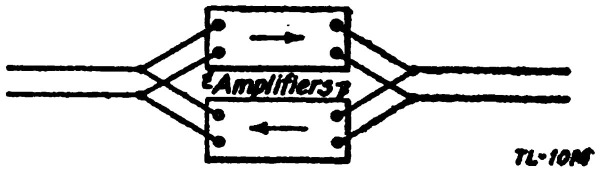

FIGURE 81.—Two-way amplifier (will cause singing).

again reaches the input of the first amplifier, and the cycle is repeated with energy, thus circulating through the two amplifiers and increasing in value until the condition of saturation is reached. The repeater then continues to "howl" or "sing" indefinitely, rendering the telephone circuit useless. In telephone repeater operation, as in duplex telegraph, we must receive incoming energy and direct it into a receiving circuit which is separate and distinct from the sending circuit. The use of amplifiers without some device for securing transmission in both directions would be restricted to such a layout as in figure 82, which would require not only twice the circuit facilities for each long distance connection, but also special telephones at each terminal. It may be recalled that duplex

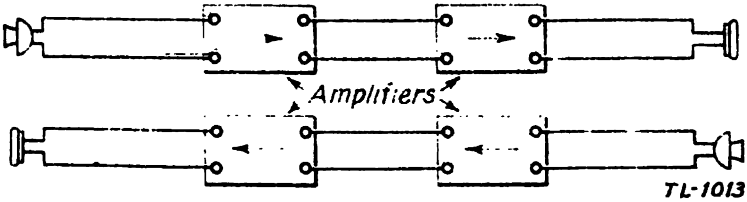

FIGURE 82.—Telephone circuit with one-way amplifiers.

telegraphy was accomplished over a single wire by application of the Wheatstone bridge principle and the use of an artificial line. The problem in telephony is somewhat more difficult, but its solution was effected by using the principle of bridge balance, using an artificial line called a "balancing network."

68. Hybrid coil.—*a.* Since an amplifier will pass current in one direction only, the amplifiers of a two-way repeater necessarily have to be placed side by side, but some device must be introduced at the point where the output of one amplifying circuit is connected to the input of the other, which will isolate the two circuits. In order to isolate these circuits and to eliminate the possibility of "repeater singing," the ordinary telephone circuit must be converted into a "receiving" and a "sending" circuit which are independent of each other, so that the energy will not be transferred around in a circle as previously described. This can be accomplished by the use of a Wheatstone bridge arrangement. A Wheatstone bridge with proper modifications can be operated as well on alternating current as on direct current. To illustrate, in figure 83 a repeating coil is connected as a Wheatstone bridge with a few simple modifications. Here the source of voltage is an alternating

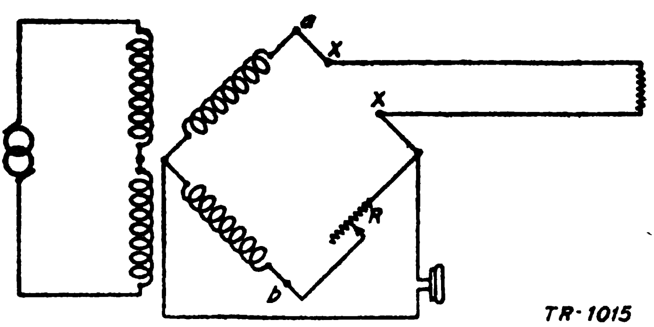

FIGURE 83.—A-c bridge.

current generator instead of a battery, and instead of connecting the voltage to the points *a* and *b* as is usually done, the same results are accomplished by connecting it across the other winding of the repeating coil. The electromotive force is then impressed across *a* and *b* by mutual inductance instead of by direct connection, but the result is the same. Since a galvanometer cannot be used with the alternating current, a telephone receiver (which for alternating current of voice frequency range is very sensitive) has

been substituted. This circuit can now be used to measure the value of any resistance that may be connected to the *X* terminals; further, this same circuit can be used to measure any impedance that might be connected to the *X* terminals, provided the variable arm *R* has in series with it a variable reactance for balancing the reactive component of the unknown impedance.

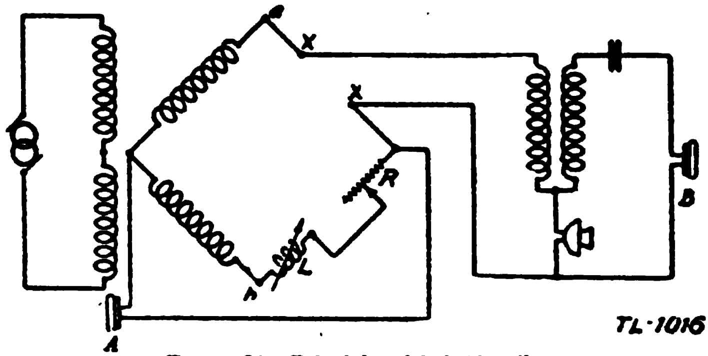

FIGURE 84.—Principle of hybrid coil.

b. With the above hook-up perfectly balanced, no sound from the generator would be heard in the telephone receiver. Suppose now that a telephone line terminating in a subset is substituted for the unknown impedance. This is shown in figure 84. You can again vary the arm of the bridge until it exactly balances the line and subset. When this is done, there will be no note in the receiver at *A* due to the audio generator, but the note can be heard in the receiver at *B*. Also any audio frequency produced at subset *B* will be heard in the receiver at *A*.

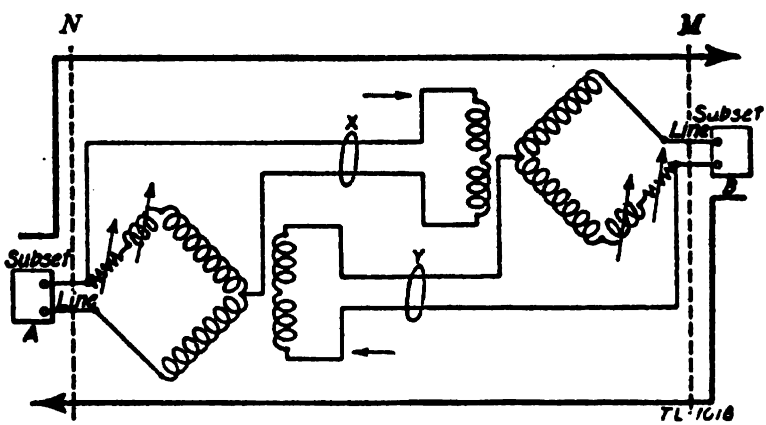

FIGURE 85.—Telephone repeater, without amplifiers.

c. If you now take two circuits, and introduce two amplifiers, at points x and y in figure 85, you have a device that may be used as a telephone repeater. It can be seen that energy in an N to M direction will pass through the repeaters as indicated by the upper arrow and energy in the M to N direction will pass through the repeater as indicated by the lower arrow. Since both the bridges are balanced, energy coming from one amplifier cannot find its way into the input of the other and cause "singing."

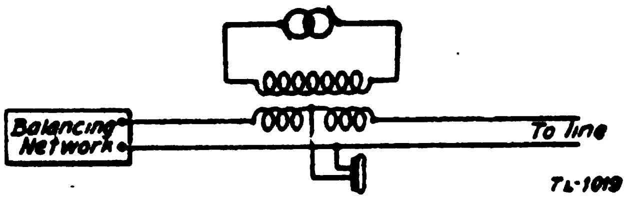

FIGURE 86.—Conventional hybrid coil symbol.

d. The coil that takes the place of the bridge mechanism in the preceding figures is known as a "hybrid coil," sometimes called a bridge transformer or "three-winding transformer." In the actual coil, however, there are a few additional details of design which do not permit the identity of the bridge circuit to be so easily recognized. The hybrid coil is conventionally shown in figure 86. It will be observed that figure 86 is really the same as figure 83, but does not resemble the Wheatstone bridge so closely. In the actual hybrid

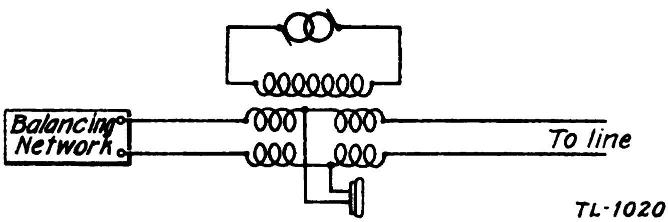

FIGURE 87.—Hybrid coil.

coil, the coils are divided and connected on both sides of the line as shown in figure 87, in order to insure symmetry of wiring, thereby reducing noise. Both sets of windings are inductively connected to the external winding.

69. The 22-type repeater.—*a. General.*—Figure 88 shows the schematic diagram of the amplifier connections to two hybrid coils in a two-wire, two-element (type 22) telephone repeater circuit. The 22-type repeater is perhaps the most commonly used. In addition to

the hybrid coils and amplifiers there are generally equalizers and low-pass filters completing the component parts of the 22-type repeater.

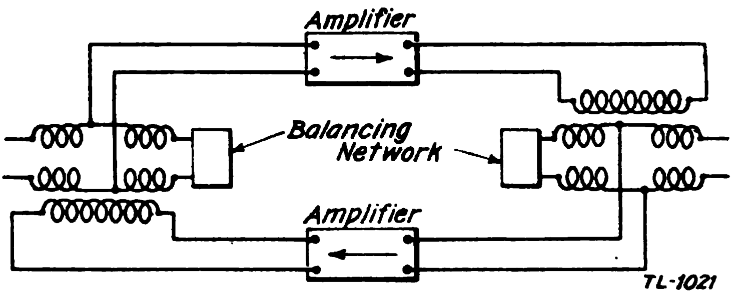

FIGURE 88.—22-type repeater.

(1) *Equalizers.*—It was explained in section VIII that high-frequency voice currents on an electrically long line are attenuated more than the low-frequency voice currents and distortion results if nothing is done to compensate for this unequal attenuation. You learned that one method of minimizing this type of distortion was to use loading coils. It is not practical to load a line sufficiently to eliminate this distortion completely. The purpose of the equalizer is to reduce this distortion further. The attenuator-type equalizer is an a-c network designed to attenuate lower frequencies more than the higher frequencies; thus the overall loss in the line and equalizer will be the same for all frequencies.

(2) *Filters.*—The low-pass filters found in voice repeaters introduce loss at high frequencies, particularly above 2500 cycles, thus reducing the tendency of the repeater to sing in the range where the balance between the balancing network and line is poor. Most of these frequencies are out of the audible range, but will overload the amplifiers, resulting in distortion and reduced gain.

(3) *Repeater gains.*—A repeater forms a closed transmission path containing gains and losses. When the sum of all the gains through this path just exceeds the sum of all the losses, singing will take place. Under ideal conditions where the line and balancing network are perfectly balanced, there is an infinite loss from the output of one amplifier circuit into the input of the other, therefore, an infinite gain could be obtained in each amplifier without any tendency to sing. Therefore, the gain of a repeater is limited by the degree of balance obtained between the balancing net-

work and the line. Unfortunately, the impedance of a line is usually rather a variable quantity because at various times it may be connected to different types of local trunks. Changing weather conditions causes the line impedance to be unstable also. Any great precision of balance is, of course, impossible under these conditons, and it is necessary in practice to resort to a compromise balancing network designed to give an approximate overall balance. In commercial practice where good balance could be obtained, the sum of the usable net gains in the transmitting and receiving circuit has been found to be approximately 30 db. The gain, of course, depends upon the degree of balance obtained.

The level of the signal at the output of a repeater is another factor which must be considered in repeater gains. As the energy level of the signal increases, the tendency to crosstalk is increased. In telephone practice the signal level is never in excess of 6 db above zero level at any point in the circuit.

70. The 44-type repeater.—Another very common form of repeater is the four-wire, four-element (44-type) telephone repeater. This repeater is used primarily on four-wire cable circuits where different cable pairs are used for transmitting and receiving. The 44-type repeater can be thought of as simply a 22-type repeater where the hybrid coils, instead of being located in each piece of equipment, are located at each end of the line with the two cable pairs connecting them. A circuit employing 44-type repeaters is shown in figure 89.

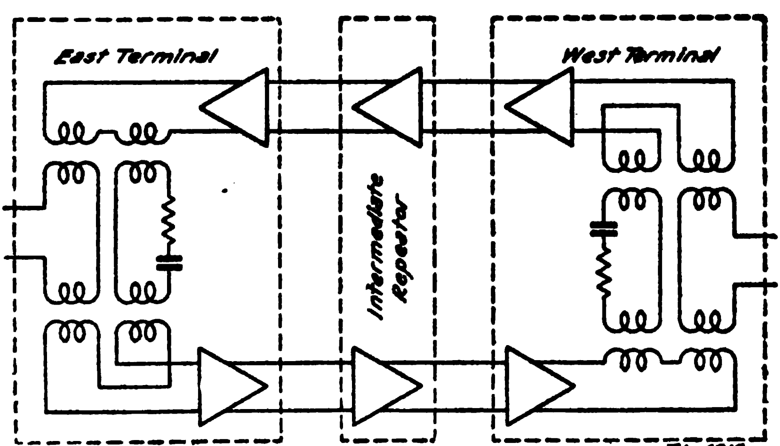

FIGURE 89.—44-type repeater.

a. Gain available.—The closed transmission path formed by the circuit now includes the losses due to the attenuation of the line. As in the 22-type repeater the total gain in the closed path cannot exceed the total losses. However, the circuit length may be increased indefinitely and as the line loss increases, the gain of the circuit can be increased proportionately without any tendency for the system to sing. The advantage of this system is that much higher gains in the repeater amplifier are possible. Two stages of amplification are used in the 44-type repeater, giving a combined gain of about 50 db without appreciable distortion. However, it is not practical to utilize all the gain available since the energy level from a noise and crosstalk consideration is the determining factor. In the 44-type repeater the input level should not be lower than 25 db below zero level and the output level should not exceed 10 db above zero level; thus the possible usable gain is 35 db.

b. Hybrid coil arrangement.—It will be noted in figure 89 that instead of the hybrid coil two repeating coils are arranged to reduce the four-wire system to a two-wire system. The principle involved here is the same as that for the hybrid coil. An analysis of figure 85 will show that the transmission loss from *x* into *y* or from *y* into *x* will be infinitely high. In figure 90 the

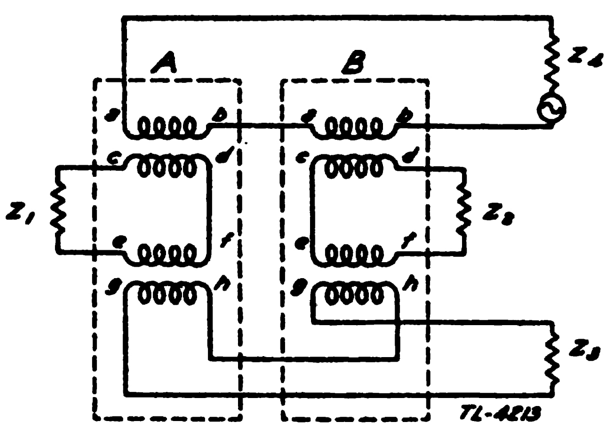

FIGURE 90.—Four-wire terminating set.

impedance of Z_2 is made equal to Z_1 and the repeating coils *A* and *B* are identical. Current flowing in the Z_4 circuit will induce equal voltage in the Z_1 and Z_2 circuits and also across the *g-h* windings of both coils, but the *g-h* winding of coil *B* is connected so that its

voltage is 180° out of phase with that of the *g-h* winding of coil *A*. Since the two voltages are equal, there will be no current flow in Z_3. One half the energy is lost in Z_2 and one half will be delivered to Z_1.

71. V1 repeater.—A recently developed repeater is the general purpose repeater, coded the V1 telephone repeater, which can be used as a four-wire repeater, a two-wire repeater, or as a four-wire repeater on one side and a two-wire repeater on the other. The advantage of this repeater is that it is very flexible. Also the amplifier circuit makes use of negative feedback, resulting in a better frequency response and lower tube noise than was obtained in the 22- and 44-type repeater amplifiers.

The V1 repeater is shown schematically in figure 91 for a two-wire arrangement. The component parts are the same as that of the 22-type. The three-winding transformer-type hybrid coil is replaced by a two-coil combination called the "hybrid repeating-coil." The two repeating coils are interconnected in such a manner as to serve the combined function of a repeating coil of proper impedance ratio and of a hybrid coil. The phantom is derived from the mid-point of two series condensers bridged across the line circuit on the repeater side of the hybrid repeating-coil. An analysis of this coil arrangement will show that again there is an infinite loss from the output of one circuit to the input of the other.

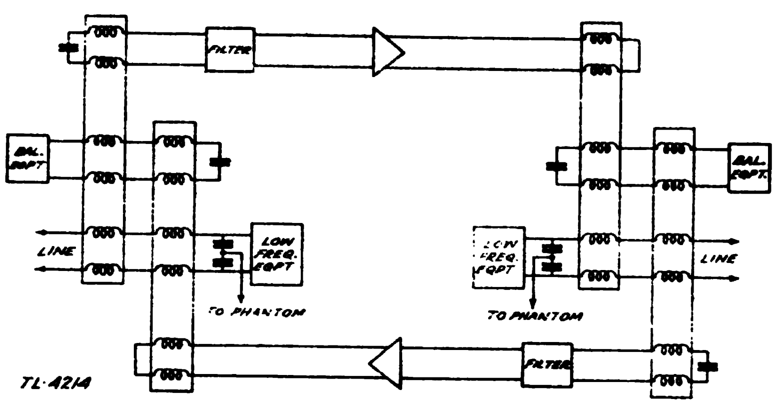

Figure 91.—Schematic diagram of V1 repeater.

72. The 21-type repeater.—Another form of telephone repeater less common than the types already mentioned is the 21-type repeater. It is a two-way, one-element device and is connected at

some intermediate point of a two-way circuit as shown in figure 92. Here the line west, which must be identical in all respects with the line east, maintains the bridge transformer balance and prevents energy from the output of the single amplifier from reaching its input. Of course, the amplified energy is divided at the midpoint of the bridge transformer and is fed to both transmitting and receiving station. This is objectionable, and since the circuit has other limitations, at the present time it is not in very general use.

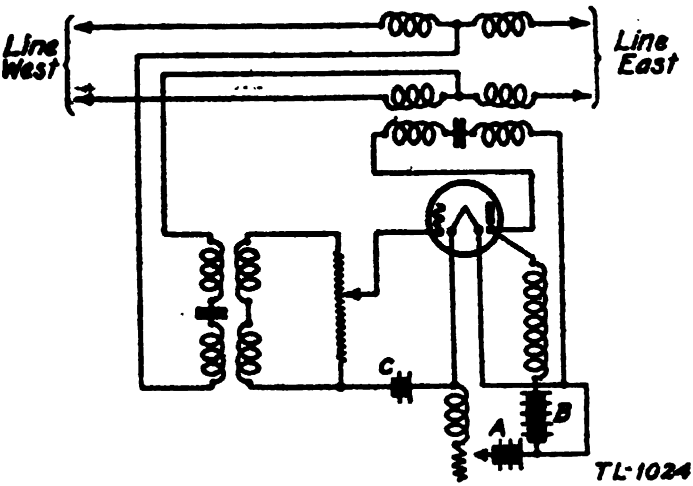

FIGURE 92.—21-type repeater.

73. Ringing over repeater circuits.—Due to the great difference in the voice signal frequency and the 20-cycle ringing frequency it is not practical to build a voice repeater that would repeat both voice and 20-cycle ringing frequencies.

a. Bypass filter.—Where the circuit is within the operating range of the 20-cycle signaling system, a low-pass filter is used to bypass the voice repeater. However, on very long lines sufficient ringing current to operate the signaling device at the distant end would be impossible to obtain without the use of repeaters.

b. Relayed signaling.—The 20-cycle ringing current may be repeated by means of relays at the repeater stations which will operate on the incoming 20 cycles. The action of this relay causes a 20-cycle supply to be connected to the line on the opposite side of

the repeater, thus relaying the 20 cycles around the repeater. This method is called relayed signaling.

c. 1000-cycle signaling.—Another method of signaling on repeater circuits is accomplished by the use of 1000-cycle ringing current. This method requires no signaling equipment at the intermediate points since the repeaters will amplify the 1000-cycle ringing current. At the terminal station, however, it is necessary to have special equipment that will convert the 20-cycle ringing current received from the switchboard to 1000 cycles, interrupted 20 times per second, to be transmitted over the line. At the distant end the same equipment converts this interrupted 1000-cycle ringing current to 20-cycle.

74. Questions for self-examination.—

1. What is a telephone repeater?
2. What is gained by the use of repeaters?
3. What determines the spacing of repeaters?
4. What is meant by "signal level"?
5. How can levels be expressed in terms of decibels?
6. What is the reference level in telephone testing?
7. What is meant by a repeater "singing"?
8. What device is used in a repeater to prevent the energy from being transferred around in a circle, thus causing the repeater to sing?
9. Draw a diagram of a hybrid coil and explain its operation.
10. What is the principle upon which the operation of this transformer is based?
11. By what means is the real line balanced?
12. What is the purpose of an equalizer?
13. What is the function of the filters used in telephone repeaters?
14. What limits the gain that can be obtained from a repeater?
15. Draw a schematic diagram of a 22-type repeater.
16. Draw a schematic diagram of a 44-type repeater.

17. What is significant of the two numerals (22, 44, 21) designating a type of repeater?

18. What is the primary difference in the type 22 and 44 repeaters?

19. What is the advantage of the V1 repeater?

20. Draw a schematic diagram of the V1 type repeater.

21. What is the disadvantage of the 21-type repeater?

22. How is ringing accomplished over circuits employing voice repeaters?

SECTION X

CARRIER SYSTEMS

75. Definition and object of carrier system.—*a. Definition.*—The term "carrier current system" is ordinarily used to cover the assembly of apparatus and equipment whereby additional telephone channels over and above the usual telephone circuits are obtained by means of carrier currents. The term "carrier" is derived from the fact that alternating currents of certain selected frequencies are employed to carry messages. More specifically, the voice frequency currents that normally flow in telephone circuits are impressed on a high-frequency carrier current, thus translating the message from the voice frequency to a higher frequency range. By means of suitable selective equipment, these message-bearing, high-frequency currents are then transmitted over existing telephone lines without interference to the ordinary voice telephone message.

b. Object.—The object of carrier telephony is the simultaneous, independent transmission of several telephone conversations over a single wire-circuit. In general, the number of communication channels is dependent only upon the number of different carrier frequencies available. In order that separation of channels may be accomplished at the receiving end, the carrier frequencies must be sufficiently far apart so that there is no interference between the transmitted bands.

76. Elements of carrier system.—The steps required to accomplish

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the desired object as mentioned above may be summarized as follows:

a. Carrier source.—There must be provided a source of high-frequency currents to be used as carriers. Vacuum-tube oscillators are used for this purpose, a separate oscillator generally being used for each different carrier frequency employed.

b. Modulation.—The message current from the terminal telephone station must be impressed upon the carrier-current wave. This process which translates the message currents from the voice-frequency range to the high-frequency range is known as modulation.

c. Transmission.—The desired products of each modulation process are then amplified and applied on the same physical circuit for transmission to the distant station.

d. Channel selection.—In order that the transmitted messages reach the proper terminal telephone, the incoming high-frequency currents must be separated and directed into the proper receiving circuits. This separation is accomplished by means of selecting circuits known as electrical filters.

e. Demodulation.—After proper channel selection is made the original message current must be restored from the transmitted side-band. This restoring process is called demodulation. After demodulation the voice signal is amplified and transmitted to the terminal telephone.

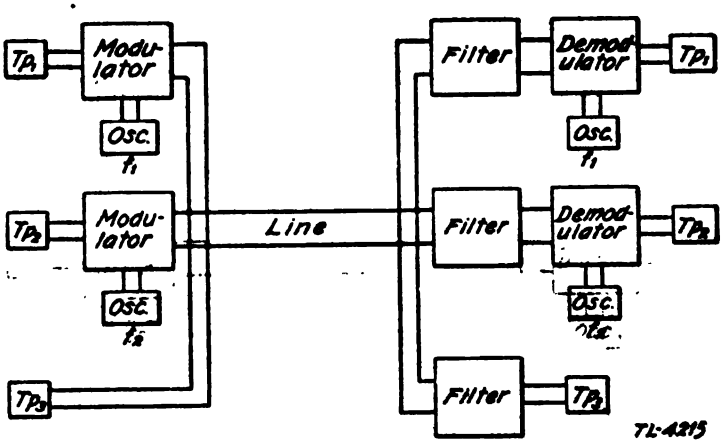

FIGURE 93.—Principle of carrier operation.

Figure 93 illustrates graphically the required steps outlined

above. While this figure provides transmission in one direction only, it will be seen that with proper arrangement of filters or selector circuits and other terminal equipment, two-way communication can be provided.

77. Modulation and demodulation.—*a. Definition.*—The process of modulation may be defined as varying the amplitude of a high frequency "carrier" current in accordance with a low frequency "signal," the voice. It is the translation of the voice-frequency signals from the original frequency range to a higher frequency range for transmission purposes. This translation of frequency is accomplished by the use of vacuum tubes, or other nonlinear impedances, as modulators. The demodulation process is identical with modulation, the frequency translation being in the reverse order.

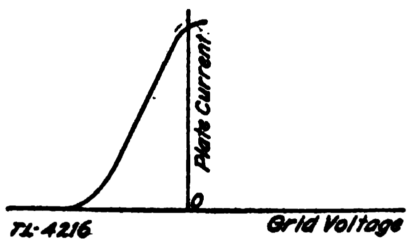

FIGURE 94.—Vacuum tube characteristic curve.

b. Modulation theory.—Referring to figure 94, it will be seen that the relation between the plate current and grid voltage is a curved line for values of grid voltage near the point of cut-off, or zero plate current. This curved or nonlinear portion of the characteristic is used for modulation as practiced in carrier systems.

If you impress two currents, one a carrier current which we will call C and the other a voice current which we will call V, on the grid of a vacuum tube, and if we adjust the grid battery voltage so that we are operating on the curved portion of the tube characteristic, the current in the plate circuit will be a function of the square of the sum of the input voltages. This output current is a complex wave composed of a number of currents of various frequencies, of which two are the useful results of modulation. These two new frequencies are the sum of the carrier and voice frequencies $(C+V)$ and the difference between the carrier and voice frequencies $(C-V)$. For example, if the carrier frequency had been 10,000 cycles and the modulating frequency (voice) 1000 cycles, you would have in the output wave, an 11,000 cycle frequency and a

9000-cycle frequency. These two new frequencies are called the upper and lower "side bands" respectively. Both of these side bands carry the characteristic of the original signal or message frequency, and either side band, combining with the carrier frequency in a suitable device, is capable of producing the original signal frequency. Either of the side bands can be transmitted to the distant end of the line and there demodulated.

c. Demodulation.—The process of demodulation requires the presence of a carrier current of exactly the same frequency as the original carrier. This may be supplied by a separate source at the receiving end, or transmitted over the line together with the transmitted side band. Modern practice is to supply the carrier at the receiving station.

Assume that you have transmitted the upper side band $(C+V)$ and are adding it, at the receiving end, with another carrier current of the same frequency as used before. In this case, you use a vacuum tube circuit similar to that used in modulation. The two voltages applied to the grid of the vacuum tube are the upper side band, $(C+V)$, and the carrier C. When the grid of the tube is properly biased, the current flowing in the plate circuit includes frequencies equal to the sum and the difference of the input voltage frequencies, namely, $(C+V)+C$, and $(C+V)-C$. This latter term is the original voice frequency message and is transmitted from the demodulator to the receiving terminal telephone, all other products of demodulation being suppressed by filters.

78. Copper-oxide varistors.—*a. Used as modulators and demodulators.*—As mentioned in the foregoing paragraph, the nonlinear characteristic of a vacuum tube creates new frequencies in the output circuit when two or more different frequencies are applied to the input. This same result is accomplished by use of other devices having nonlinear input-output characteristics. More recent design practices have replaced the vacuum tube with copper-oxide *varistors* as modulators and demodulators. This device is capable of accomplishing the same results as the vacuum tube and with a considerable reduction in equipment cost, maintenance, and space.

b. Properties of copper-oxide unit.—The copper-oxide disc unit, in addition to passing current in one direction only, possess an additional characteristic in that the resistance across the unit varies with the magnitude and polarity of the applied voltage. These facts make varistors particularly adaptable for use as modulators.

The units are very stable in operation and apparently after initial aging they deteriorate no further.

79. **Filters.**—*a. Definition.*—Electrical filters are circuits designed to present a very low impedance to currents of one frequency range and very high impedance to currents of a different frequency range. Thus, currents of the first frequency range will pass through such a circuit with very little or no loss, while currents of the other frequency ranges will suffer high attenuation or be suppressed entirely. Filters are made up of combinations of inductances and capacitors. The impedance of an inductive circuit increases directly with the frequency while the impedance of a capacitor decreases as the frequency increases. The circuit arrangement determines the type of filter.

b. Classification.—Filters may be generally classified as "low-pass", "high-pass", and "band-pass". They differ mainly in the arrangement and magnitude of the inductances and capacities.

(1) *Low-pass filters.*—If you make up a combination of inductances and capacitors as shown in figure 95, the inductance being in series with the line and the capacitors across the line, you have a form of low-pass filter which provides high attenuation to higher frequencies and very little loss to low frequencies. The series, or inductive, branches are low impedance at low frequencies, hence low frequency currents will pass through the filter. The inductances offer high impedance and the parallel capacitive branches low impedance to high frequency currents. Consequently, high frequency currents do not reach the output side of the filter.

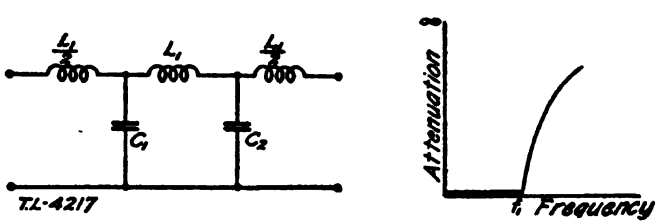

FIGURE 95.—Low-pass filter circuit and attenuation characteristic.

(2) *High-pass filters.*—If you reverse the position of the inductances and capacitors and connect them as shown in figure 96, the transmitted frequencies are above and the suppressed ones are below a certain critical frequency.

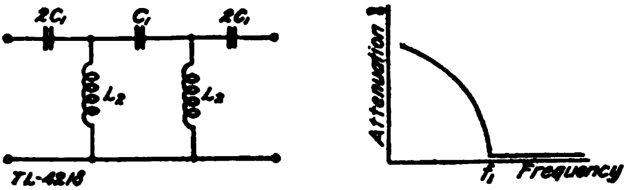

FIGURE 96.—High-pass filter circuit and attenuation characteristic.

(3) *Band-pass filters.*—The essential elements of the low-pass and the high-pass filters having different critical frequencies can be combined in one filter of the form shown in figure 97. This filter is representative of the band-pass type, transmitting frequencies within the range f_1 to f_2.

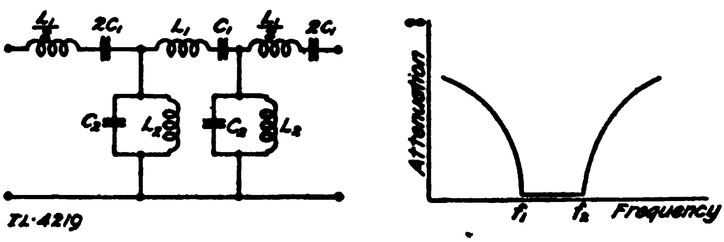

FIGURE 97.—Band-pass filter circuit and attenuation characteristic.

(4) *Tuned circuit.*—The simple resonant circuit, figure 98, is, in effect, a simplified form of band-pass filter which transmits only a narrow frequency band. It is used in certain carrier circuits.

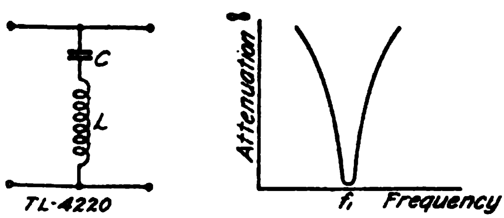

FIGURE 98.—Resonant circuit and attenuation characteristic.

c. *Uses.*—The high-pass and low-pass filters are generally used for separating the voice frequency channels from the carrier channels. Another use is for providing directional selectivity, that is, separating east-bound channels from west-bound channels. The band filters are more generally used for separating the individual

channels from each other and for suppressing the undesired products of modulation and demodulation.

d. Crystal filters.—Multi-channel, high-frequency carrier systems employ filters made of quartz crystal. These crystals are very high grade filters having a sharp cut-off at the frequencies used, giving better quality and allowing a wider range of frequencies to be transmitted.

80. Types of carrier systems.—Carrier systems are designated by an alphabetical code in the order of development. They may be divided into two general classes, "low frequency" and "broad band" sytems.

a. Low frequency systems.—Under this category are those systems designed for use over open wire lines and frequencies up to 30,000 cycles. These include the types *A*, *B*, *C*, *D*, *G*, and *H* of which types *A*, *B*, and *D* are no longer manufactured. The systems most commonly in use today are the type *C*, a three channel system, and the type *H*, a single channel system.

b. Broad band systems.—Types *J* and *K* systems, each providing twelve communication channels, employ a frequency range from 12 to 200 kc. Type *J*, designed for use on open wire lines, is a two-wire system employing filters for directional selectivity. Since type *K* is a four-wire system, designed for use on cable circuits, the same frequencies are used in both directions of transmission.

c. Coaxial system, type L.—The most recently developed carrier system, type *L*, is designed for use on coaxial conductors. Such a system affords as many as 500 telephone circuits from a pair of coaxial conductors.

81. Transmission range.—The low frequency carrier systems are comparatively short range systems. Without the use of repeaters, the transmission range extends from 50 to 200 miles depending upon the type of system. This distance can be extended by the use of repeaters. However, the use of too many repeaters may introduce distortion and maintenance problems. The broad band type of carrier systems are toll, or long distance, systems although they require the use of repeaters at very frequent intervals. Type *J* requires a repeater approximately every 50 miles; type *K*, 16 miles; type *L*, 5 miles. This is economically feasible since the repeater amplifier handles the entire frequency range, thus amplifying all channels of the system with one repeater.

82. Frequency allocation.—The chart of figure 99 shows the channel frequency allocation of carrier telephone systems most commonly found in use today. From this chart, it will be seen that a type *C* and type *J* system can be superimposed on the same wire

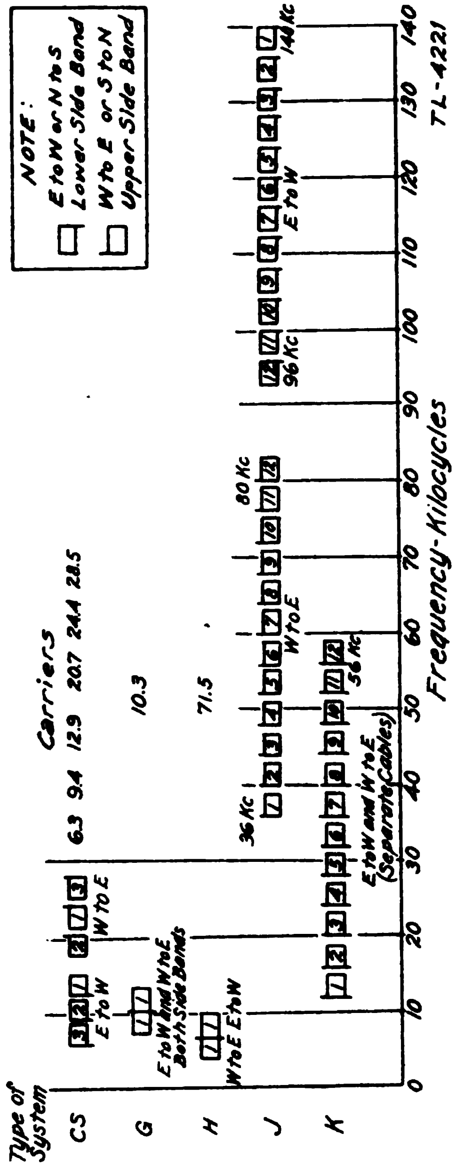

FIGURE 99.—Frequency allocation chart, carrier telephone.

line already carrying a voice channel, thus providing sixteen telephone channels on one pair of wires.

83. Signaling.—Ringing over a carrier system is accomplished by utilizing a signal frequency which falls within the voice range yet carries a 20-cycle characteristic necessary to operate ringers or drops. A frequency of 1000 cycles interrupted at a 20-cycle rate is provided for this purpose. Each channel carrier is modulated with this 1000-20-cycle signal from a separate source. The process of modulation, transmission, and demodulation, are the same as for a voice signal. After demodulation, the 20-cycle characteristic of the 1000-20-cycle frequency is picked up by a detector circuit and 20-cycle current applied to the signaling circuit to operate the switchboard drop.

84. Questions for self-examination.—

1. Define the term, "carrier current."

2. From what source are carrier currents obtained?

3. What are the four major steps necessary to accomplish transmission by carrier?

4. Explain briefly how the voice frequency current and carrier frequency current are combined in a modulator to produce the desired side-band.

5. What is meant by the term "side-band"?

6. What properties of a copper-oxide disc unit make it useful as a modulator?

7. Name several advantages of using varistors as modulators.

8. Why does an electrical filter pass currents of one frequency range and suppress all others?

9. What is the principal difference between a low-pass filter and a high-pass filter?

10. What requirement must be met in order to operate more than one carrier system over a single pair of wires?

11. How many communication channels are available when using a type *H* and type *J* carrier over an existing voice circuit?

12. What signaling current frequency is used in carrier systems?

13. Why is it necessary to have a frequency of this nature?

Section XI

LOCATING AND CLEARING TROUBLE

85. General.—Trouble may be defined as any undesirable condition which impairs the efficiency of a communication system. From the electrical or mechanical standpoint, there are two fundamental sources of trouble. They are:

a. A connection where one should not be.—This will include shorts, crosses and grounds.

b. No connection where one should be.—This will include broken wire, loose connections and high resistance joints. These same troubles may be classified as to their manner of appearance, either permanent or intermittent. The permanent troubles are those which exist in a steady state long enough for them to be analyzed and cleared. The intermittent troubles come and go at irregular and unpredictable periods, and exist for short periods of time only. This type of trouble is the hardest to analyze and clear, as the maintenance man can never be certain whether he cleared the trouble or it cleared itself and still remains as a potential source of future trouble.

86. Recognition and analysis of trouble.—A great deal of difficulty is usually encountered in getting personnel trained to the point where they will quickly detect trouble, analyze it and determine the proper procedure to be followed in locating and clearing it. As soon as a case of trouble manifests itself, the maintenance man should ask himself the following questions: What happens that should not occur, or what doesn't happen that should occur? What

could cause this particular type of trouble? Is it in the equipment or the line? How should testing proceed so as to definitely determine the trouble? To avoid undue delay, it is important that the maintence man proceed with deliberation and forethought.

87. Test equipment.—*a. Voltmeter.*—To determine definitely the nature and location of trouble, certain tests must be made. Several types of equipment are available for making these tests, but usually they consist of a battery, voltmeter, and certain key arrangements. When the above equipment is embodied in a test set, the key arrangement is set up so as to give the following circuits:

(1) The battery, voltmeter, and line all in series (fig. 100).

(2) Either side of the line in series with the battery, voltmeter, and ground (fig. 102).

(3) The voltmeter in series with the line (fig. 104).

(4) Either side of the line in series with the voltmeter to ground (fig. 105).

(5) Any of the above circuits may be reversed either at the line or voltmeter.

b. Field telephone.—The field telephone can also be used to advantage if other test equipment is not available. After the primary tests have been made, the repairman should not attempt to take the heavy test set out on the line because the field telephone can tell him everything that he needs to know after the testboard man has analyzed and measured the trouble.

c. Wheatstone bridge.—The Wheatstone bridge is an instrument used when accurate resistance measurements must be made. It allows the use of a method of measurement by which the resistance of a fault will not prevent accurate measurement of line resistance to the fault. The instructions for use of the instruments are contained in the lids and will not be covered in this text. Considerable practice in the use of a bridge is necessary in order that personnel using it can obtain dependable results. An example of a bridge is the standard Signal Corps test set I-49. Other bridge-type test sets are listed in the Signal Corps General Catalogue.

d. Receiver and battery.—A telephone receiver connected in series with a battery and suitable test leads may be used for testing continuity of a circuit. When a circuit is completed through a resistance a click will be heard and another click will be heard when the circuit is broken. If the receiver and battery are connected

in series with a condenser, a click will be heard when the circuit is made, but none when it is broken. With experience the maintenance man can obtain a rough indication as to the degree of the condition found, by the loudness of the clicks.

e. Receiver only.—When used at common-battery installations the use of an extra battery may be eliminated since a source of battery is available at many parts of the equipment to be tested. A receiver may also be used to advantage at times to give an idea of the approximate location of an open on one side of a comparatively long pair. Noise between each wire and ground is observed separately and the two compared.

f. Test lamp.—A test lamp may be used in the same manner as a receiver to give a visual rather than an audible indication. The lamp should have a voltage rating equal to the battery with which it is to be used. The brilliancy of the lamp will be an indication of the resistance of the short. A lamp will not, however, give an indication of capacitance when used with a battery, nor will it operate on the wide range of currents which will give clicks in a receiver.

88. Methods of testing.—*a. Test for short.*—First have the equipment at the distant end removed from the line. This should be the first thing done whenever tests are to be made. Otherwise, a false indication may be obtained. After this has been done, certain keys are operated so that the line to be tested is placed in series with the voltmeter and battery, and the deflection of the voltmeter needle will indicate the degree or resistance of the short. In this case, as indicated by figure 100, the needle will remain steady at a definite reading, and by use of the formula $X=\frac{R(V-V')}{V'}$, the resistance to and including the short can be determined. In the above formula X, is the unknown resistance, R is the resistance of voltmeter used, V is the battery voltage and V' is the reading of the voltmeter when the above test was made. After X has been calculated, it is quite simple to determine the approximate distance to the short when the resistance per unit length of the wire is known. It is to be remembered that the resistance as determined from the formula includes the resistance of the fault as well as the line to the fault. Calculations therefore show the maximum distance to the fault; the actual location may be somewhat closer to the testing end than calculated.

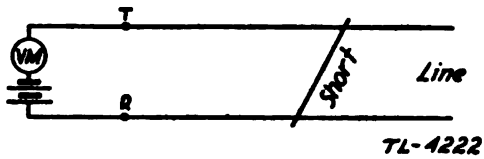

FIGURE 100.—Circuit used to test for short.

b. Test for a cross with another line.—In testing for a cross, the same procedure is used as when testing for a short, except that the wires of two separate pairs are used as shown in figure 101. This trouble is usually indicated by crosstalk between two independent metallic circuits.

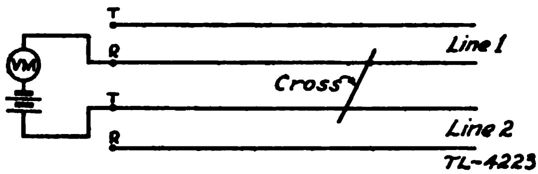

FIGURE 101.—Testing for a cross.

c. Test for ground.—When testing for a ground on a circuit, one side of the line is placed in series with voltmeter, battery and ground as shown in figure 102. If a steady reading is obtained, the equipment at the distant end should be removed, and then it will be possible to determine which side of the line is grounded.

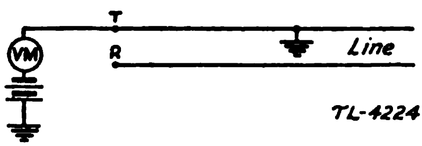

FIGURE 102.—Testing for ground.

d. Test for an open.—Under the best conditions, it is only possible to make a rough approximation as to the distance to the open. The best way to get an estimate is to set up the equipment as shown in figure 103. Due to the proximity of the wire to the ground, there is an appreciable capacitance between each wire and ground so that when battery is applied to one wire and ground, the capacitance will take a charge. Now by reversing the battery connection quickly, the capacitance will be discharged and charged in the opposite direction. This flow of current will give a momentary reading or kick on the voltmeter. If this value is compared to one obtained

on a wire of known length going over the same route. it is possible to estimate the distance to the open.

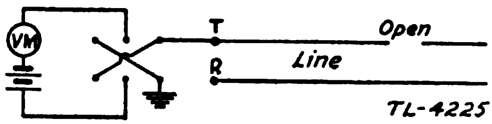

FIGURE 103.—Testing for an open.

e. Test for foreign battery.—(1) To test for foreign battery between the two conductors, first connect the voltmeter directly across the line as shown in figure 104. If the line has foreign voltage applied between the two conductors from any source, the voltmeter will indicate this fact. After the voltage condition has been determined between the two conductors, each conductor should be

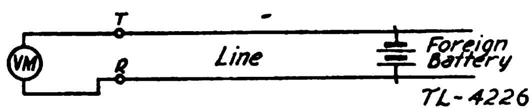

FIGURE 104.—Testing for foreign voltage between wires.

tested separately with respect to ground as shown in figure 105. The fact that foreign voltage is on the line will usually be indicated by erratic results obtained while testing for shorts or opens. If the foreign battery aids the test battery, the voltmeter will indicate the sum of the two voltages, and if the foreign battery opposes the test battery, the voltmeter will indicate the difference between the two voltages.

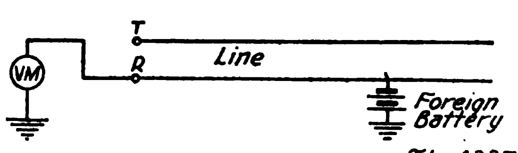

FIGURE 105.—Testing for foreign voltage to ground.

(2) After the testboard man has made all of the above tests he can analyze the trouble and usually tell the approximate distance to the trouble. It is then the duty of the lineman to go out on the line, find the trouble with the aid of the information given him and clear the trouble from the circuit.

f. Testing for a short with the field telephone.—Under normal conditions the lineman should not take the heavy test equipment out on the line but should take a field telephone instead. In case he is looking for a short he should go to the approximate location as indicated by the test man, open the line and test as shown in figure 106. If the lineman has passed the short he will ring the subset, but

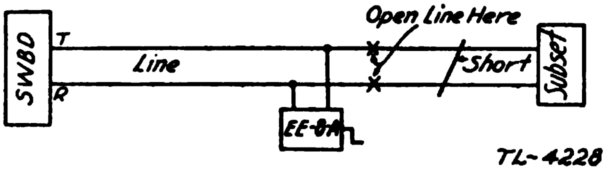

FIGURE 106.—Test for short with field telephone.

if he hasn't passed the short he will get the switchboard. After determining on which side of the short he is located, the lineman will again move towards the short. He will keep this up until the trouble has been bracketed, and then by inspection, and further tests if necessary, the trouble is finally located and cleared.

g. Testing for an open with the field telephone.—It is very simple to test for an open with a field telephone. It is unnecessary for the lineman to cut the line to test in, as shown in figure 106. All he

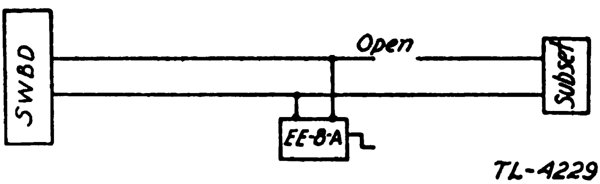

FIGURE 107.—Testing for open with field telephone.

need do is clip his test leads to the line and see whom he can call (fig. 107) and then proceed to bracket and repair the trouble.

When testing a circuit it is important that the person making the test ask himself what the particular test is for and what the results of the test indicate. The man responsible for locating and clearing trouble should be a man who does not get excited under pressure.

89. Inside trouble.—Inside troubles refer to troubles found in equipment inside the telephone office or in the switchboard equipment at the command post. These troubles are of the same general

nature as outside troubles, with a few additions. Crosses, shorts, grounds and opens are in general tested in the same manner as the outside troubles. Open circuits are usually the result of blown fuses, burned out lamps, or dirty contacts on the keys, relays or jacks. Adjustments on the relays, other than burnishing the contacts, should not be attempted by any one except a specially trained switchboard man with the special instruments and tools for this particular work.

90. Preventive maintenance.—By making routine tests many cases of potential trouble can be detected and cleared before they cause interruptions of service. By use of gages and known constants a test man can determine when the equipment has become worn to the point where it needs replacement or repair. He can also tell when certain parts are getting out of adjustment. The repairman can then take these reports and make the necessary repairs and adjustments. Without routine tests these potential sources of trouble would not appear until they were serious enough to prevent efficient operation.

91. Questions for self-examination.—

1. What is meant by trouble with respect to communication systems?

2. What are the two fundamental sources of trouble?

3. How are troubles classified as to their manner of appearance?

4. When trouble appears, what is the first thing to be done?

5. What questions should the maintenance man ask himself as soon as trouble appears?

6. What pieces of apparatus are usually incorporated in test sets?

7. Should the test set be taken out on the line by the lineman?

8. What circuit is set up for testing for a short circuit?

9. How is a test for a cross made?

10. What circuit is set up to test for a ground?

11. When testing for an open what causes the voltmeter kick?

12. What circuit is set up to test for foreign battery?

13. How is the presence of foreign battery detected?

14. What is a short? A ground? A cross? An open?

15. When using a field telephone to test for a short on a line, what procedure should be followed?

16. When using a field telephone, how would you test an open line?

17. What are inside troubles?

18. What are some of the more frequent inside troubles encountered?

19. What is preventive maintenance?

20. Why is preventive maintenance important?

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APPENDIX I

INDEX TO TECHNICAL AND FIELD MANUALS
(See FM 21-6 for complete list)

APPENDIX II

GLOSSARY OF TERMS

The following definition of words and terms apply only to their usage in this text.

Alternating current.—Current that periodically reverses in direction.

Alternator.—An a-c generator.

Ammeter.—A current meter with a scale calibrated in amperes.

Amplifier.—A device which, under control of a current or voltage of given characteristics, produces a larger current or voltage of similar characteristics.

Amplitude.—In connection with alternating current or any other periodic phenomena, the maximum value of the displacement from zero position.

Anode.—The terminal or electrode from which electrons leave an electron tube.

Antisidetone circuit.—A telephone circuit that materially reduces sidetone without reducing the output of the telephone; *without sidetone*. (See Sidetone.)

Armature.—The rotating assembly of a d-c motor or generator; also the movable iron part which completes the magnetic circuit in certain apparatus.

Attenuation.—The decrease in amplitude of electrical energy as it passes through a device or circuit.

Attenuator.—A device for producing attenuation; usually calibrated to produce known amounts of attenuation.

Battery.—A device for converting chemical energy into electrical energy; one or more cells.

Bell.—A device which will operate on either alternating or direct current (a-c or d-c) and give continued striking of a gong, producing a clear ringing sound.

Bias.—*Line bias.*—The effect on the length of telegraph signals produced by the electrical characteristics of the line and equipment. If the received signal is longer than that sent, the distortion is called marking bias; if the received signal is shorter, it is called spacing bias.

Applied bias.—A force (electrical, mechanical, or magnetic) exerted on a relay or other device which tends to hold the device in a given electrical or mechanical condition.

Break contact.—That contact of a switching device which opens a circuit upon the operation of the device.

Bridge.—A shunt path; a device used in the electrical measurement of impedance, resistance, etc.

Buzzer.—An electrical device producing a buzzing sound, usually by use of a vibrator.

Bypass.—A shunt path around some element or elements of a circuit.

Capacitance.—The ability or capacity to receive an electrical charge.

Capacitive reactance.—The effect of capacitance in opposing the flow of alternating current.

Capacitor.—A device for inserting the property of capacitance into a circuit; two or more conductors separated by a dielectric.

Carrier current.—A current used in the transmission of intelligence impressed upon it.

Carrier frequency.—The frequency of the carrier current.

Cathode.—The negative terminal or electrode in an electrolytic cell, vacuum tube, or other electrical apparatus, from which electrons flow.

Cell.—A combination of electrodes and electrolyte which converts chemical energy into electrical energy.

Channel.—A band of frequencies or a circuit within which communication may be maintained.

Characteristic.—A distinguishing trait, quality, or property.

Circuit.—A closed path or mesh of closed paths which may include a source of emf.

Commutation.—The mechanical process of converting alternating current, which flows in the armature of d-c generators, to direct current as furnished to the load.

Commutator.—The part of d-c rotating machinery which makes electrical contact with the brushes and connects the armature conductors to the external circuit and accomplishes commutation.

Commutator ripple.—The small pulsations which take place in the voltage and current of d-c generators.

Component.—A part of the whole; e.g. pulsating direct current (the whole) consists of an a-c component (one part) and a d-c component (another part).

Condenser.—Same as capacitor.

Continuity.—A condition of a circuit where a closed electrical path is obtained.

Contactor.—A device for closing and opening electrical circuits remotely; a magnetically operated switch.

Coupling.—Term used to represent the means by which energy is transferred from one circuit to another.

Cross.—A type of line trouble in which one circuit becomes connected to one or more other circuits.

Crossfire.—A condition where telegraph signals on one circuit cause interference in other telegraph or telephone circuits.

Crosstalk.—A condition where conversation on one circuit causes interference in other telephone circuits.

Current.—A flow of electrons in a circuit.

Cycle.—In a periodic phenomena, one complete set of reoccurring events.

Decibel.—A unit of transmission expressing a relation between input and output power; equai to ten times the common logarithm of the ratio of input to output power.

Demodulator.—A nonlinear device for removing the modulation component (usually voice frequency) from a modulated carrier wave.

Density.—Concentration of anything; quantity per unit volume or area.

Direct current.—Current which is constant in direction.

Differential.—Pertaining to, or involving, a difference; i.e., a differential current device is one which operates upon the basis of a difference in two current values.

Distortion.—An alteration or deformity of a wave form.

Drop.—*a. Switchboard drop.*—An electrically operated mechanical device on a switchboard line circuit which is used to indicate an incoming call.

b. Drop side of a circuit.—That side of the circuit toward the switchboard drop.

c. Drop wire.—The overhead wire connecting a subscriber station with either open wire or cable.

Electrode.—The solid conductors of a cell or battery which are placed in contact with the electrolyte; a conductor which makes electrical contact with a liquid, gas, or an electron cloud.

Electrolyte.—A solution in which, when traversed by an electric current, there is a liberation of matter at the electrodes, either an

evolution of gas or a deposit of a solid. Usually refers to the solution in a battery.

Electromagnet.—A core of magnetic material, such as soft iron, which is temporarily magnetized by passing an electric current through a coil of wire surrounding it, but loses its magnetism as soon as the current stops.

Electromotive force.—*emf*—Difference of electrical potential or pressure measured in volts.

Electron.—One of the negative particles of an atom.

Energy.—That capacity for doing work.

Equalizer.—A network having an attenuation complementary to that of a telephone line, for the purpose of equalizing the attenuation at the frequencies used.

Field of force.—Region in space within which a force is effective.

Filter.—A device for preventing the passage of current of certain frequencies while allowing currents of other frequencies to pass.

Flux.—The magnetic lines of force.

Force.—That which tends to change the state of rest or motion of matter.

Frequency.—In periodic phenomena the number of vibrations or cycles in unit time; in alternating current the number of cycles per second.

Function.—The duty or job performed by a device.

Fundamental.—A primary or necessary principle; basis; the lowest frequency component of a complex wave.

Fuse.—A circuit protecting device which makes use of a conductor which has a low melting point.

Gain.—The amount of amplification; negative attenuation.

Generator.—A device for converting mechanical energy into electrical energy.

Ground.—The contact of a conductor with the earth; also the earth when employed as a return conductor.

Grouping circuits.—Circuits used to connect two or more switchboard positions together so that one operator may handle the operation of those positions from his own operator's set.

Handset.—A telephone in which the transmitter, receiver, and a connecting handle form a single piece.

Harmonics.—Frequencies of exact multiples of a fundamental frequency.

Heat coil.—A protective device consisting of a coil of wire wound around a copper tube inside of which a pin is soldered. It is so de-

signed that if an excessive current passes through it for a period of time the heat generated will melt the solder, releasing the pin, and grounding the line.

Holding coil.—A separate coil of a relay which is energized by the operation of the relay and holds the relay operated after the original operating circuit is deenergized.

Howler.—An electromechanical device for the production of an audio-frequency tone.

Hybrid coil.—A multi-winding transformer designed to be used in a circuit where currents in one portion of the circuit induce voltages in all branches except certain designated ones in which no voltage is induced.

Impedance.—The total opposition to the flow of current, consisting of resistance and reactance.

Inductance.—Property of a circuit which opposes a change in current.

Induction.—The act or process of producing voltage by the relative motion of a magnetic field and a conductor.

Inductive reactance.—The opposition to the flow of alternating or pulsating current due to the inductance of the circuit.

Instantaneous value.—When a value is continually varying with respect to time the value at any particular instant is known as the instantaneous value.

Insulator.—A medium which will not conduct electricity.

Intermediate distributing frame.—A frame upon which the circuits from a switchboard and other apparatus are brought out to terminals.

Interposition trunks.—Trunks between different positions of a switchboard.

Jack.—In combination with a plug, a device by which connections can readily be made in electrical circuits.

Key.—A hand operated device for the rapid opening and closing of a circuit or circuits.

Leakage.—Term used to express current loss through imperfect insulation.

Level.—The amplitude of a signal as compared to that of a signal chosen as reference; in telephony, reference level is considered as that signal producing one milliwatt of power in a 600-ohm load; usually measured in decibels (db) above (+) or below (−) a reference level.

Lines of force.—A path through space along which a field of force acts. (Shown by a line or lines on a sketch.)

Loading coil.—A coil designed to be inserted in a line to add inductance to the line.

Loop.—*a. Subscribers loop.*—The pair of conductors connecting a subscriber's telephone with the main frame of the central office.

b. Loop mile, resistance of.—A pair of conductors between two points one mile distant, the resistance of the conductors connected in series.

Magnetic pole.—Region where the majority of magnetic lines of force leave or enter a magnet.

Magnetism.—The property of the molecules of certain substances, as iron, by virtue of which they may store energy in the form of a field of force, due to the motion of the electrons in the atoms of substance; a manifestation of energy due to the motion of a dielectric field of force.

Magnetomotive force.—*mmf*—The force which is necessary to establish flux in a magnetic circuit or to magnetize an unmagnetized specimen.

Main distributing frame.—A frame upon which are brought out the incoming cable or open wire lines to terminals and protectors.

Make contact.—That contact of a device which closes a circuit upon the operation of the device.

Megohm.—A unit of resistance; equal to one million ohms.

Microfarad.—Practical unit of capacitance; one-millionth of a farad.

Milliampere.—Unit of electric current; equal to one-thousandth of an ampere.

Milliammeter.—Current meter with a scale calibrated in milliamperes.

Modulator.—A nonlinear device for changing the amplitude (or frequency) of a carrier wave at a rate corresponding to the signal to be transmitted.

Multiple.—Parallel connection whereby any number of identical pieces of equipment may be connected into the circuit.

Mutual inductance.—Inductance associated with more than one circuit.

Network.—An electrical circuit made up of series or shunt impedances or combinations of series and shunt impedances.

Noise.—An electrical disturbance which tends to interfere with communication over the circuit.

Ohm.—Fundamental unit of resistance.

Ohmmeter.—A direct reading instrument for measuring resistance, calibrated in ohms.

Oscillator.—A device for producing electrical oscillations; an electrical circuit for converting direct current into alternating current.

Pad.—A network, consisting of resistance, connected so as to have a given amount of attenuation at all frequencies; usually symmetrical.

Parallel circuit.—A circuit in which one side of all component parts are connected together to one line while the other side of all components are connected together to another line.

Patching.—Temporarily connecting together two lines or circuits by means other than switchboard cord circuits.

Patching cord.—A cord terminated on each end with a plug, used in patching between circuits terminated in jacks.

Period.—The time required for the completion of one cycle.

Permanent magnet.—A piece of steel or alloy which has its molecules lined up such that a magnetic field exists without the application of a magnetomotive force.

Phantom circuit.—A telephone circuit which is superimposed upon two other circuits so that the two conductors of one circuit act combined as one conductor for the phantom circuit, and the conductors of the second circuit act as the other phantom conductor.

Plug.—In combination with a jack, a device by which connections can readily be made in electrical circuits.

Potential difference.—The degree of electrical pressure exerted by a point in an electrical field or circuit in reference to some other point; same as electromotive force or voltage.

Private branch exchange (P.B.X.).—A small private exchange acting as a branch of the main exchange for a subscriber with a large number of telephones between which considerable traffic is handled.

Protector.—A device to protect equipment or personnel from high voltages or currents.

Protectors, open-space cut-out.—A device consisting of two carbon blocks, one connected to one side of a line and the other to ground, separated by a narrow gap, designed to provide a path to ground for high voltages such as lightning, etc.

Pulsating current.—Current of varying magnitude but constant direction.

Receiver.—An electromechanical device for converting electrical energy into sound waves.

Rectifier.—A device for changing alternating current to pulsating current.

Reflection.—The returning of a portion of an electrical wave to the sending end of the circuit.

Relay.—A device for controlling electrical circuits from a remote position; magnetic switch.

Repeater.—A device for the retransmission of a signal, usually with amplification.

Repeating coil.—An audio-frequency transformer for transferring energy from one electrical circuit to another, usually one-to-one ratio with one side (line connection) arranged so that a center tap may be obtained for simplexing.

Resistance.—The opposition offered by a conductor to the passage of either direct or alternating current. That portion of impedance which causes power loss.

Resonance.—The condition of a mechanical device or electrical circuit adjusted to respond to a certain frequency.

Retardation coil.—A coil offering high impedance to voice frequency currents but low impedance to direct current.

Rheostat.—A variable resistance for limiting the currents in a circuit.

Ringer.—An audible signaling device which will operate only on alternating current to give a clear ringing sound.

Rotor.—The rotating part of an electrical device.

Self inductance.—Inductance associated with but one circuit.

Series circuit.—An electrical circuit in which the component parts are placed end-to-end and form a single continuous conductor; opposite of parallel.

Short.—A type of line trouble in which the two sides of a circuit become connected together.

Shunt.—A parallel or alternate path for the current in a circuit; usually with some impedance other than zero; not used with reference to trouble. (See Short.)

Side-band.—The band of those frequencies equal to the carrier plus the voice frequencies (upper side-band), or carrier minus the voice frequencies (lower side-band).

Sidetone.—That portion of the signal from a transmitter in a telephone which is returned to the receiver of that telephone.

Signal to noise ratio.—The ratio of the signal level on a circuit to the noise level of the same circuit.

Simplex.—A method of obtaining a telegraph channel by use of repeating coils or bridged impedances.

Singing.—Oscillations produced by feed-back in a circuit, especially in repeaters.

Space charge.—An electrical charge distributed throughout a space; such as a charge between the filament and plate of a vacuum tube.

Stator.—That part of an electrical device which remains stationary when in use.

Sub-cycle generator.—A frequency reducing device which furnishes ringing power at a sub-multiple of the power supply frequency.

Subscriber.—A person or organization to whom service is extended.

Subset.—The complete telephone equipment including handset, ringer, and other associated parts located at a subscriber station, exclusive of protective equipment.

Supervision.—The process of watching over the condition of a connection at a switchboard to determine when subscribers are through using the connection.

Switch.—A device for opening, closing, or rerouting an electrical circuit.

Switchboard.—A board containing apparatus for controlling or connecting electrical circuits.

Synchronism.—The state of being synchronous.

Synchronous.—Having the same period and phase; happening at the same time.

Tandem office.—A telephone office handling connections between smaller offices located in a group around it. It handles no direct connections to subscribers but serves only to connect one telephone office with another.

Telephone.—An instrument for the converting of speech into electrical waves for transmission and converting electrical waves to sound waves for reception.

Telering.—A frequency selector device for the production of ringing power; for the production of 20-cycle ringing power from a 60-cycle source it selects every third half-cycle of the input to be used as a half-cycle of the output frequency.

Terminal.—One end of an electrical circuit.

Transfer circuits.—Same as grouping circuits.

Transformer.—A device for raising or lowering a-c voltage.

Transmission.—The passing of energy through a conductor.

Transmitter.—That part of a telephone which converts the sound

waves into electrical waves; usually consists of a diaphragm operated by the sound waves to compress a container of carbon granules, causing a change in resistance and thus in currents to correspond to the sound waves.

Transposition.—A rearrangement of the relative position of adjacent wires, to prevent losses or interference by induction.

Trunks.—A circuit between two switchboards, central offices, switchboard positions or other parts of a telephone plant, but not to any subscriber.

Varistor.—A combination of dissimilar metals in contact which give a nonlinear impedance.

Voice frequencies.—Those frequencies covered by the range of human voice.

Volt.—Unit of potential, potential difference, emf, or electrical pressure.

Voltmeter.—An instrument for measuring potential difference or electrical pressure, calibrated in volts.

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WAR DEPARTMENT

TECHNICAL MANUAL

COMMON-BATTERY TELEPHONE EQUIPMENT

September 3, 1942

TECHNICAL MANUAL No. 11-458 } WAR DEPARTMENT, Washington, September 3, 1942.

COMMON-BATTERY TELEPHONE EQUIPMENT

SECTION I
GENERAL

1. Purpose.—The purpose of this text is to acquaint the student with the basic fundamentals governing common-battery telephony.

2. Scope.—The general application of various circuits and combination of circuits used in common-battery telephony is discussed in this text. On the other hand no attempt is made to cover special application of the various circuits in specific equipment if the circuits employed are covered in existing technical manuals issued by the Signal Corps.

SECTION II
COMPARISON OF LOCAL-BATTERY AND COMMON-BATTERY SYSTEMS

3. Local-battery system.—The distance over which satisfactory telephone communication is possible is determined by the electrical characteristics of the circuit. These characteristics are, in some measure, affected by the type of outside plant construction, which, in turn, depends upon the number of subsets served and the expected life of the system.

a. Advantages.—The advantages of the local-battery system over the common-battery system are:

(1) The wire lines, usually called the outside plant, can be constructed more quickly and cheaply.

(2) For the local-battery system the switchboard is less complex, less delicate, and less costly.

(3) Transmission of speech is possible over long high resistance lines because the current in the line has a much smaller value.

b. Disadvantages.—(1) The life of a dry cell is short; it deteriorates even when standing idle, and the voltage varies radically between the time of installation and exhaustion. Hence, from an economic consideration, dry cells are one of the most expensive sources of electrical energy.

(2) As the voltage decreases, the output of the telephone will decrease, consequently, uniform service will not be obtained at any one subset.

(3) Checks must be made at each telephone set to test the batteries and replace exhausted cells. In commercial companies, this entails visits to the subset at perhaps isolated locations.

(4) In addition to the batteries, a means must be provided for the user to signal the operator. This is accomplished by a magneto (hand generator) which not only further increases the size of the set, but requires effort on the part of the user in turning the generator crank when signaling.

(5) Failure on the part of the person using this type of telephone to ring off, when through talking, increases the work of the operator. This necessitates monitoring by the operator to determine when to disconnect, and also reduces the availability of the circuits.

(6) If the switchboard drops are the manual restoring type, this further adds to the operator's work.

4. Common-battery system.—*a. Advantages.*—The use of the common-battery equipment overcomes all of the above disadvantages as follows:

(1) By furnishing all current from a centrally located battery, the drain on it is such to warrant the use of storage batteries which are easier and more economical to maintain. Recharging energy for a storage battery costs a great deal less than does the purchase of dry cells—the service requirements being the same.

(2) The talking current for the subsets is supplied from the storage batteries which hold their voltage constant, thus the output of the subset is not affected by battery deterioration.

(3) The battery supply being thus centralized, located at the telephone central office, eliminates the necessity of visiting subsets to test and renew batteries.

(4) The removal of the receiver or handset from the hookswitch allows a circuit to be completed for direct current which causes a lamp to light on the switchboard which signals the operator. (The operation of the component parts of the subset is discussed in detail in the next section.) Hence, the magneto is not required and with the elimination of the dry cells, the subset equipment is smaller and simpler.

(5) The operation of the hookswitch, when the receiver is removed—or hookswitch signaling—not only simplifies the routine for persons placing calls, but affords a prompt means of indicating completion of the conversation to the operator, resulting in reducing the operator's work.

(6) A single operator can handle many more lines on a common-battery switchboard than one at a local-battery switchboard and also give better service.

b. Disadvantages.—As compared to the local-battery system, the disadvantages of the system are:

(1) The outside plant must be of higher quality in order to reduce leakage from the potential standing on the lines.

(2) Any unbalance in the wire lines of the outside plant will seriously affect quality of transmission and distance over which transmission of speech is possible.

(3) The inside plant equipment is far more complex, expensive and delicate, therefore, a longer time is required for installation, and maintenance requirements are increased.

(4) The resistance of the loop or line to the subset limits the distance over which transmitter and signaling current may be supplied to a subset.

5. Application or uses of the two systems.—The common-battery system is used where there are a great number of subscribers located in a relatively small area and the local-battery system used where the subscribers are reasonably scattered. From the standpoint of quality of outside military plant (generally field wire), reliability of switchboard equipment, and quality of transmission over field wire, it has been found that common-battery equipment is not as well suited for *field* military telephone systems as is local-battery. Generally, the common-battery system will give better service where the local traffic is heavy and hence, is used by the army in higher headquarters where a number of subsets are concentrated in a relatively small area. The local-battery system is used where conditions do not permit the use of the common-battery equipment.

6. Questions for self-examination.—

1. Why are dry cells such an expensive source of electrical energy for a telephone system?
2. Give three advantages of a common-battery system over a local-battery system.
3. How does a common-battery subscriber signal the operator?
4. What components are there in a local-battery telephone which are not necessary in a common-battery telephone?
5. Under what conditions has a local-battery system advantages over the common-battery system?

SECTION III
THE COMMON-BATTERY TELEPHONE

7. Components of the common-battery telephone.—It was stated in section II that it is unnecessary to have a hand generator and a battery in a common-battery telephone. The other components of a local-battery subset, namely: receiver, transmitter, induction coil, ringer and hookswitch are all found in a common-battery subset. In addition to these five pieces of equipment, there is one other that is necessary in the common-battery subset, a capacitor. The usual common-battery subset, therefore, contains six component parts. The hookswitch, transmitter, receiver and ringer are identical with those used in the local-battery subset.

8. Common-battery induction coil.—Since the battery supply for talking is from a central source, the transmitter must be in series with the line instead of in an isolated circuit as in a local-battery telephone. The induction coil (an audio-frequency transformer) is used to electrically couple the secondary circuit to the primary circuit. Since the secondary circuit is a local circuit, it is unnecessary to pole the receiver. The resistance of the receiver is also removed from the primary circuit. There are two main types of common-battery induction coils. They are known as the sidetone and antisidetone induction coils. The sidetone induction coil has two windings and a typical example is the Western Electric 46-type coil. The resistance of its L_1–R (primary) winding is 14.7 ohms and the GN–C (secondary) winding is 9.5 ohms. The turn ratio of the primary to the secondary is 17 to 14, or approximately one to one.

a. Antisidetone induction coil.—The antisidetone induction coil has three windings and a typical example is the one used in the Automatic Electric Co., Monophone Type 40 subset. The resistance of its 1-2 (primary) winding is 28 ohms, the 3-4 (secondary) winding is 14 ohms, and 5-6 (tertiary) winding is 65 ohms. The turn ratio between the primary and secondary is approximately the same as in the sidetone induction coil, but this ratio will vary with the different makes depending on the requirements of the circuit in which they are used. The newer types of induction coils, such as the one just discussed, have closed magnetic paths. This gives them a greater degree of efficiency and they can be made more compact.

9. Capacitor.—The common-battery subset requires either one or two capacitors depending on the type of circuit used. The sidetone subset needs only one capacitor which performs two functions. It keeps direct current out of the ringer and also acts in the so-called booster circuit to increase the output of the subset. On the other hand, the antisidetone circuit requires separate capacitors to perform these functions.

10. Common-battery sidetone subset circuit.—The circuit of the common-battery subset may be developed in a logical manner. Battery for talking purposes is fed to the telephone from a central source

so it may be assumed that battery is connected in some way to the terminals L_1 and L_2 of the telephone. The primary circuit of the subset, consisting of the transmitter and primary of the induction coil must be connected directly in series with this power source. Figure 1 shows a diagram of this circuit. The receiver is coupled to

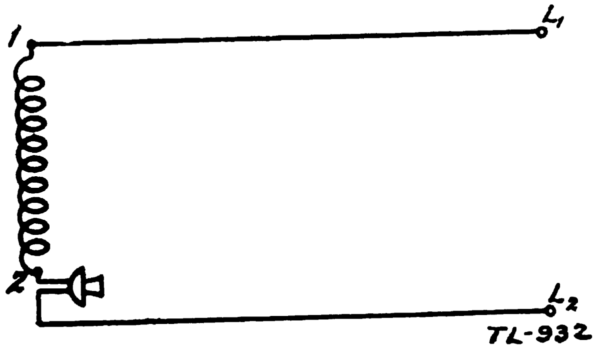

FIGURE 1.—Primary circuit.

the primary circuit by means of the secondary winding of the induction coil as illustrated in figure 2. This circuit is called the secondary circuit. The operation of these two circuits is as follows·

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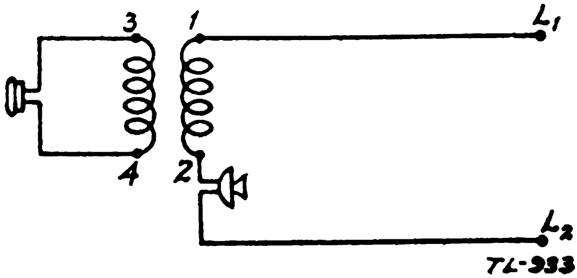

FIGURE 2.—Primary and secondary circuits.

There is direct current flowing in L_1, through the transmitter and out L_2, and the transmitter is able to vary this current by the action of its diaphragm on the carbon granules. This variable current in the primary causes a variable voltage to be induced in the secondary, which causes a corresponding variable current to flow through the receiver, giving an appreciable amount of sidetone. Sidetone may be defined as that sound heard in the receiver due to the sound picked up by the transmitter of the same subset. An incoming signal produced at the distant end of the line passes through the primary of the induction coil, the transmitter and back to its source. This signal, a varying current, induces a voltage in the secondary circuit which causes a current to flow through the receiver where it is changed to an audible sound. Since the operator is signaled in common-battery telephony by completing a path for direct current through the local subset, the necessity for opening the primary circuit between calls becomes evident. To do this a

hookswitch is inserted in the circuit as shown in figure 3. Since there is no direct current path through the secondary circuit, it is unnecessary to break that circuit.

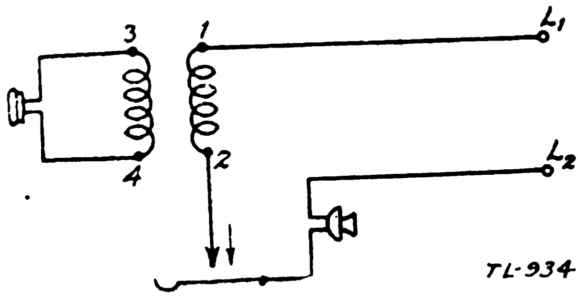

FIGURE 3.—Primary and secondary circuit with hookswitch added.

The local subscriber can now transmit and receive and he can also signal the operator, but the operator cannot signal the subscriber, so a ringer must be added for this purpose. The ringer must be across the line but it must not provide a direct current path. To accomplish this, a capacitor is placed in series with the ringer which allows 20-cycle ringing current to pass but blocks the direct current. Figure 4 illustrates the ringer circuit added to the telephone. This is a complete basic common-battery telephone circuit.

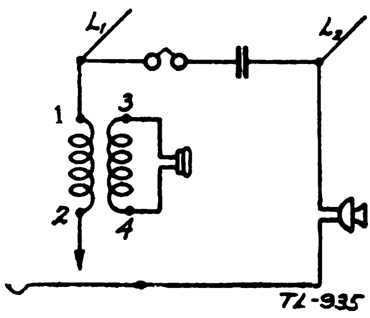

FIGURE 4.—Basic common-battery subset.

11. Booster subset.—Some years ago, the Western Electric Company developed a subset circuit which is a considerable improvement over that shown in figure 4. This circuit is known as the booster circuit and is now used in nearly all common-battery telephones. The same identical parts are used, but the capacitor and transmitter are also included in the receiver circuit. This is done by connecting terminal *3* of the induction coil to the point between

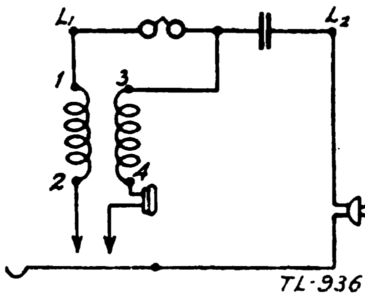

FIGURE 5.—Booster subset.

the ringer and capacitor and bringing one side of the receiver down to a hookswitch contact. Figure 5 shows a diagram of the booster circuit. By comparing figures 4 and 5 it can be seen exactly what changes in wiring are necessary to change from one to the other. With the circuit as shown in figure 5 it is necessary to open the receiver circuit also at the hookswitch, otherwise, there is a complete path for direct current from L_1 to L_2. This circuit is considerably more efficient in transmitting than was the one previously discussed.

12. Explanation of booster circuit.—The student should refer to figure 6 for this explanation. It is identical with figure 5 except

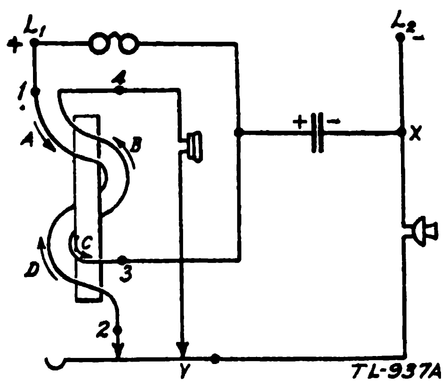

FIGURE 6.—Booster subset equivalent circuit.

that the induction coil windings are shown around the core in the direction they actually are in the coil. This makes it easier to understand how the circuit functions. Assume the transmitter is at rest. It has a certain normal resistance and direct current is flowing from the source, over the positive side of the line L_1, through *1-2* winding of the coil in direction of arrow *A*, hookswitch contact, transmitter, L_2, and back to source. Between the points *x* and *y* there is a certain voltage, the *IR* drop across the transmitter. The capacitor is charged by this same voltage with polarity as shown the diagram.

Now suppose some one speaks into the transmitter in such a way as to lower the resistance. This reduces the voltage between the points x and y, and demands an increase in the line current. This means that the capacitor can no longer hold its entire charge, so a discharge will take place from the positive side of the capacitor, through the *3-4* winding, receiver and transmitter to the negative side of the capacitor. The direction of this discharge is through the *3-4* winding as indicated by arrow *B*. This flow of current in the *3-4* winding in the direction of *B* will induce an electromotive force in the *1-2* winding in the direction of arrow *A*. Thus, the direction of this induced electromotive force in the *1-2* winding is such as to aid the transmitter at this instant in increasing the current in the line.

The next instant the resistance of the transmitter will increase. Thus the voltage between x and y increases and the line current must decrease. As the voltage between x and y has increased, current will flow to the positive side of the capacitor from y, charging the capacitor until the voltage across it equals that between x and y. This pulse of current is in the direction of arrow *C* through the *3-4* winding, inducing an electromotive force in the direction of arrow *D* in the *1-2* winding. Thus the induced electromotive force now aids the transmitter in reducing the line current. It will be seen that the current changes taking place in the telephone line are of much greater range than without the booster hook-up. The charge and discharge of the capacitor is made to aid the transmitter in changing the line current.

In receiving, the action of the circuit is simpler than for transmitting. As the resistance of the transmitter does not change, there is no charge and discharge of the capacitor. Assume an impulse coming in over L_1. It flows down through the *1-2* winding inducing an impulse upward in the *3-4* winding. This induced impulse flows around the receiver circuit, through the receiver, transmitter and capacitor, and produces the sound waves heard at the receiver. When the original impulse of current reaches the hookswitch, it finds a choice of two paths; one through the transmitter to L_2 and out, the other through the receiver, *3-4* winding, and capacitor to L_2. The impulse will divide in inverse ratio to the impedance of these two paths, much the larger part going through the transmitter. The portion which flows through the *3-4* winding is in the opposite direction to the induced impulse, weakening it to some slight extent. However, the gain in transmitting much more than offsets the loss in receiving.

13. Sidetone-reduction circuit.—Under certain conditions, such as noisy surroundings, it may become desirable to eliminate all pos-

sible sidetone. In modern telephones this is done by using an antisidetone circuit which bypasses the receiver with a balancing network without impairing the transmitting efficiency of the telephone. In the older types of telephones the reduction in sidetone is accomplished by neutralizing the booster circuit which reduces the transmission output of the telephone. The resulting circuit is known as the sidetone-reduction circuit. In this circuit the transmitter is shifted to a different location in the circuit as is shown in figure 7. This shift in the location of the transmitter reduces the sidetone but it completely destroys any action by the booster circuit. By inspection it may be seen that the capacitor is no longer in multiple with the transmitter and consequently it is no longer subject to a varying voltage.

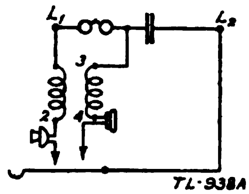

FIGURE 7.—Sidetone reduction circuit.

14. Combined hand telephone set TP–6.—*a.* Since the utilization of common-battery telephone systems in the higher units of the army, the Signal Corps has accepted as standard the type known commercially as the "combined hand telephone set." This telephone is known as the TP–6 and includes sets made by various manufacturers as follows:

Automatic Electric 40–AA–52
Western Electric 302–AW–3
Stromberg-Carlson 1212–ABZ
Kellogg 925 BA
North Electric 2–H4–SL–S

All working parts in these sets are combined in the handset and stand, thereby eliminating the use of a separate bell box. The mounting contains the switchhook, ringer, induction coil, and condensers. The specific design and method of connecting the parts into the telephone circuit varies with each manufacturer, therefore, several will be covered separately in this paragraph.

The handset is of the conventional type, consisting of a receiver of the watch case design and a non-positional transmitter, both of which are mounted in a plastic handle so shaped that when the receiver is held to the ear, the mouthpiece falls into the natural talking position. Due to the close mechanical coupling between receiver and transmitter, an antisidetone circuit is utilized to prevent howling. This circuit also allows an effective receiving gain, by

partially eliminating the local noises from the receiver; as sidetone is reduced, the user, hearing his own voice only faintly, tends to speak louder, thus also providing an effective transmission gain. A description of the sets follows:

b. Automatic Electric Co. Type "40-AA-52 Monophone."—The diagram below shows the fundamental circuit arrangement of the A.E. combined set and will be used for explanation.

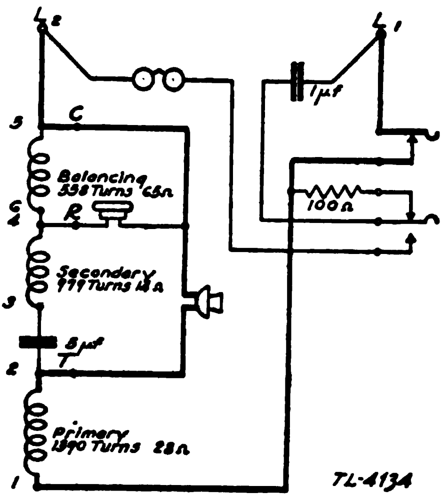

FIGURE 8.—Simplified circuit diagram of the Automatic Electric Co. Type 40-AA-52 Monophone.

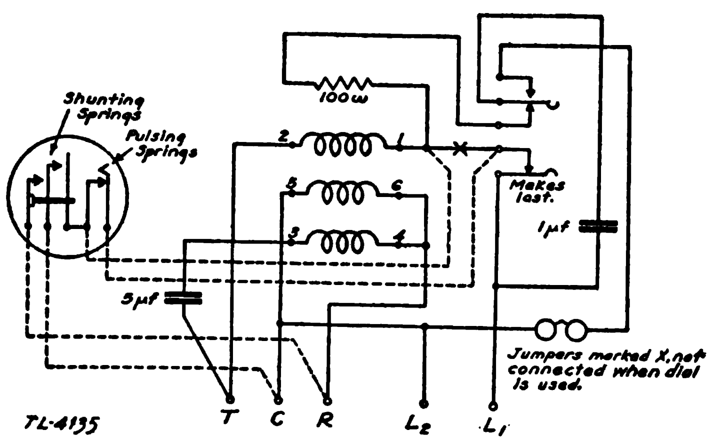

FIGURE 9.—Circuit diagram of the Automatic Electric Co. Type 40-AA-52 Monophone.

Figure 8 is a simplified diagram broken down so that the circuits can more easily be followed, while figure 9 is the conventional schematic diagram showing the various parts in their electrical and mechanical relationship.

The apparatus contained in the mounting functions as follows:

5-μf. condenser.—Part of the booster circuit to increase transmission output.

1-μf. condenser.—Keeps direct current from flowing through ringer. It also acts with the 100-ohm resistor as an arc suppressor across contact *X* and across the dial contacts when the dial is used.

Hookswitch.—Breaks the primary circuit and closes the ringer circuit when the handset is placed on its cradle.

100-ohm resistor.—Dissipates energy from the arc surge when the hookswitch contact is opened, or when a number is dialed.

Induction coil—1-2 winding.—This is the primary winding and is in series with the transmitter and line. It has 28 ohms resistance.

3-4 winding.—This is the secondary winding and has a resistance of 14 ohms. With the 5-μf. capacitor, transmitter and receiver, it forms the secondary or receiving circuit.

5-6 winding.—This is the tertiary or balancing winding and in this case is bridged directly across the receiver.

Ringer.—The ringer circuit, composed of the ringer and the 1-μf. capacitor, is completed through the hookswitch. This is done so that when the telephone is in use, the ringer is removed from across the line; also when used on dial systems, the bell cannot be activated while dialing.

The antisidetone feature is provided by the *5-6* section of the coil. The voltage induced in this coil section on transmission is opposite and equal to the *IR* drop in the coil and consequently the resultant voltage drop between terminals *C* and *R* is zero and no current will flow through the receiver. When receiving, the voltage induced in the *5-6* section of the coil is in the opposite direction and equal to the applied voltage on this coil, and consequently no current will flow through this coil, but it will all follow the alternate path through the receiver.

The dotted lines in the diagram show the circuit when the dial is used. In this case the jumper marked with an *X* is removed.

c. Western Electric Co. 302 Set.—It will be noted from the following diagram of the Western Electric 302 set that it has, with very few exceptions, the same circuit as the Automatic Electric Type 40 Monophone.

There are four major differences between this circuit and the A.E. Co. circuit:

(1) The ringer is not connected through the hookswitch, therefore, it remains across the line continuously.

(2) There is no separate resistance to absorb the arc across the hookswitch contacts. However, when there is excessive arcing across the pulsing contacts of the dial, a filter, consisting of resist-

ance and capacity may be connected into the circuit to absorb the arc.

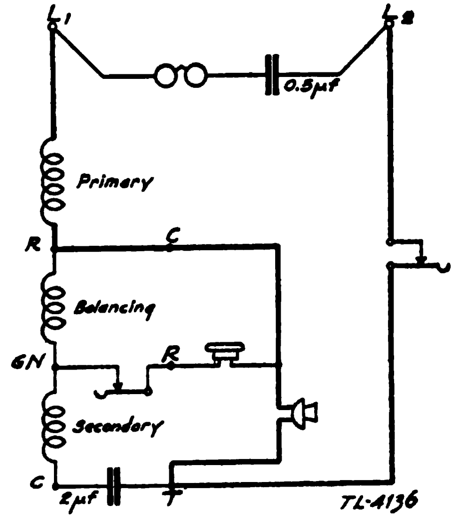

FIGURE 10.—Simplified circuit diagram of the Western Electric Co. No. 302 Set.

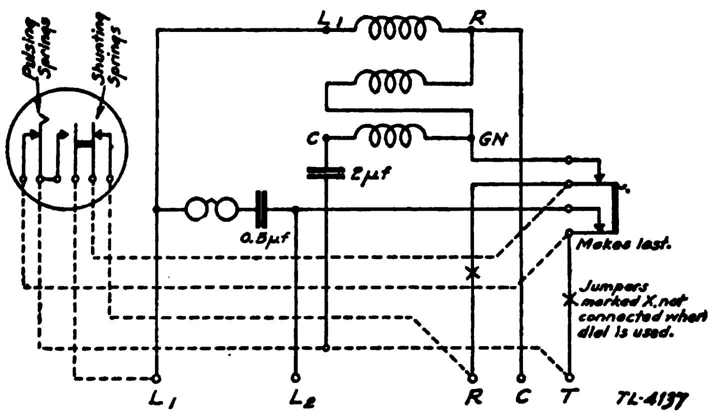

FIGURE 11.—Circuit diagram of the Western Electric Co. No. 302 Set.

(3) When the dial is used, the receiver circuit is opened during the dialing period instead of being shunted as in the A.E. set.

(4) By referring to the simplified schematic diagram figure 10 it will be noticed that the arrangement of the windings of the coil is different, but the way in which the balancing winding operates is exactly the same as was explained above under the Automatic Electric Co. telephone. Other than differences in design peculiar to the two manufacturers, the two telephones are, with the above exceptions, alike.

d. Kellogg Co. "Masterphone."—This telephone utilizes a different type circuit to suppress sidetone. The K. S. & S. Co. call it a Triad circuit.

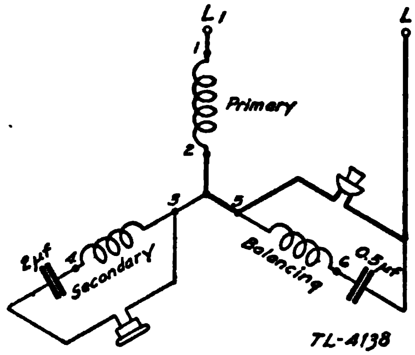

FIGURE 12.—Simplified circuit diagram of the Kellogg Co. "Masterphone."

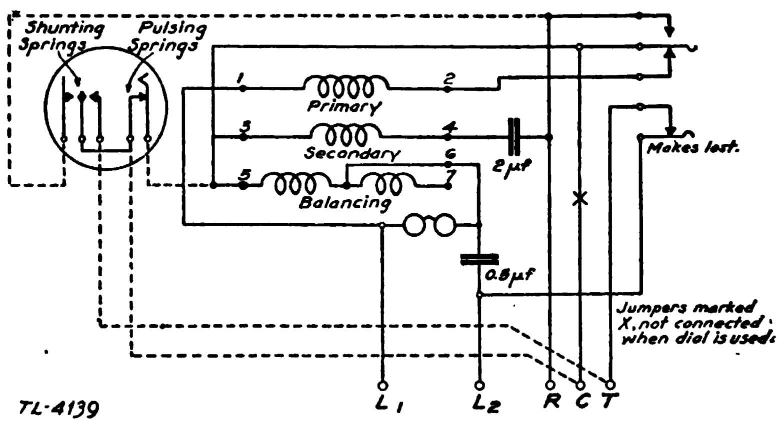

FIGURE 13.—Circuit diagram of the Kellogg Co. "Masterphone."

The 0.5-μf. condenser prevents the flow of direct current through the ringer, suppresses the arc across the pulsing contacts of the dial, when it is used on dial systems, and acts in the booster circuit to increase the transmission efficiency of the telephone.

The coil windings function as follows: *1-2* section is the primary winding; the *3-4* section is the secondary winding; and the *5-6* section is the balancing and booster winding.

In the following discussion refer to figure 12. The antisidetone circuit of this telephone is different from those previously discussed. When transmitting, we will assume that the transmitter diaphragm has just been depressed. A current increase will take place flowing from *1* to *2* in the *1-2* section of the coil, and the 0.5-μf. condenser will discharge, causing a current to flow from *6* to *5* through the *5-6* section of the coil. The voltages induced by

these currents in the *3-4* section of the coil are opposite and cancel each other and as a result no current will flow in the receiver.

When receiving, it will be assumed that the instantaneous current flow will be from *1* to *2* in the *1-2* section of the coil. This current will induce a voltage in the *6* to *5* direction in the *5-6* section of the coil. This voltage is equal to the *IR* drop across the transmitter, consequently there is no voltage difference between the two sides of the 0.5-μf. condenser and no current will flow through the *5-6* section of the coil. As a result, the only voltage induced in the *3-4* section of the coil is that from the current in the *1-2* section and a strong current will flow through the receiver.

e. Stromberg-Carlson telephone 1212 ABZ.—The diagrams below show the circuit arrangement of this telephone, and by referring to them through the following discussion a better understanding will be obtained.

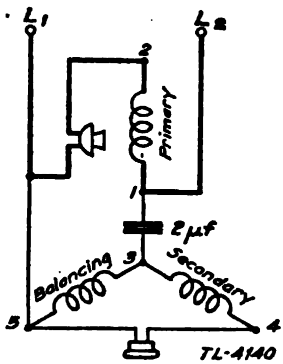

FIGURE 14.—Simplified circuit diagram of the Stromberg-Carlson telephone 1212 ABZ.

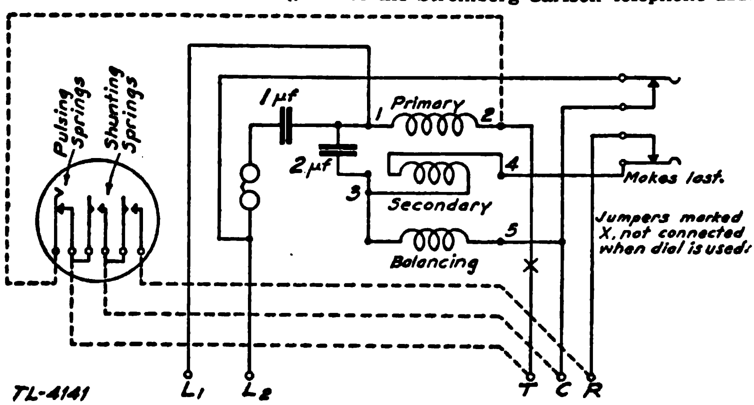

FIGURE 15.—Circuit diagram of the Stromberg-Carlson telephone 1212 ABZ.

The 1-μf. condenser serves merely to keep direct current from flowing through the ringer.

The 2-μf. condenser acts in the booster circuit and keeps the direct current out of the receiver.

The three windings of the coil function as follows: *1-2* is the primary winding, *3-4* is the secondary winding, and the *3-5* winding is the balancing winding for the antisidetone circuit.

Refer to figure 14. It will be seen that on transmission, when the resistance of the transmitter drops, current will increase in the *1-2* winding. Assume that this increase is in the *2* to *1* direction. At the same time the condenser discharges through the *3-5* winding in the direction *3* to *5*. These currents will induce a voltage in the *4* to *3* direction in the *3-4* winding. This voltage is equal and opposite to the *IR* drop across the *3-5* winding and as a result there is no voltage difference between terminals *4* and *5* of the coil and no current will flow through the receiver. When receiving, assume an instantaneous applied voltage which will cause a current to flow from *1* to *2* through the *1-2* winding. This current will induce a voltage in the *5* to *3* direction in the *3-5* winding and in the *3* to *4* direction in the *3-4* winding. In this case the two voltages are additive and cause a large current to flow through the receiver.

15. Types of common-battery telephones.—Common-battery telephones are made in four types: the wall, the desk stand, the hand-set, and the combined set. The wall type is a unit including all the parts except transmitter and receiver in one box. Desk stands are in two units; the bell box housing the ringer, induction coil and capacitor, and the desk stand containing the transmitter, the hookswitch and support for the receiver. Hand-sets are in three units: the bell box housing the ringer, induction coil and capacitor; the hand-set mounting containing the hookswitch; and the hand-set consisting of the transmitter and receiver. Combined sets are in two units; the base housing the ringer, induction coil, capacitors and switch, and the hand-set consisting of the transmitter and receiver.

16. Questions for self-examination.—

1. Name the component parts of a common-battery subset.
2. Does the receiver differ in any respect from the one used in a local-battery subset?
3. Is the receiver connected so that current from the central office battery flows through it? Why?
4. Does the transmitter differ in any respect from the one used in a local-battery subset?
5. From what source is the talking current obtained?
6. Why is an induction coil used in a common-battery subset?
7. How does this coil differ from the one used in a local-battery subset?

8. What is the turn ratio between the primary and secondary of the coil?

9. Would it be possible to use a common-battery subset in which the receiver and transmitter were connected in series with the line, using no induction coil? Why?

10. Why is a capacitor placed in series with the ringer in a common-battery subset?

11. What is meant by a "booster" circuit?

12. Is this circuit widely used?

13. Explain the booster action.

14. Is the transmission efficiency increased or decreased by use of the booster type of circuit? Why?

15. Is the receiving efficiency increased or decreased by the use use of the booster type of circuit? Why?

16. What is meant by "sidetone?"

17. Draw a diagram of talking circuit using a receiver, transmitter, and induction coil. Show the battery hooked across the line.

18. When no one is talking, what kind of current is flowing in the primary winding? In the secondary winding?

19. Assume one party talking; what kind of current is flowing in the primary winding? In the secondary winding?

20. What is the Signal Corps type number of the common-battery subset adopted by the Signal Corps?

21 What is the difference between the antisidetone and the sidetone reduction circuits?

22. What is meant by antisidetone circuit?

23. Does the antisidetone circuit effect the efficiency of the subset on transmission? On reception?

24. Is it necessary to have a hand generator in a common-battery subset?

25. What are the four types of common-battery telephones in general use?

SECTION IV
SUBSCRIBER LOOPS

17. Definition.—The pair of conductors carrying the voice currents from the protectors at the central office is known as the subscriber loop. This loop may consist of drop wire, open wire, or cable pairs, each of different size wire and different type construction.

18. Station protectors.—*a. Air-gap protectors.*—In a discussion of subscribers loops, the first thing to be considered is the station protector. This usually consists of two 7-ampere fuses (will pass 7 amperes and blow out at 10½ amperes) in series with the line and a pair of carbon-block air-gap protectors to ground on the station side of the fuses. The air-gap protectors consist of two carbon blocks separated by approximately .003 inch. One of the two carbon blocks is connected to ground and the other one to the other conductor. A pair of blocks is used between each conductor and ground. These blocks then provide protection against high voltage to ground, such as lightning, which will arc across the gap. This arcing, however, will cause carbon dust to collect in the gap and this may cause trouble necessitating cleaning the gaps.

b. Fuses.—The fuses are of the long enclosed tubular type and are always located toward the exposed section of the line from the air-gap protector blocks so that if the exposure to a high voltage, which arcs across the air-gap protector, is prolonged the fuses will open the circuit should the current become excessive. One of the reasons for the fuses being rated at 7 amperes is because most constant-current series street-lighting circuits are automatically regulated to maintain their currents at 6.6 amperes. When a break occurs in such a circuit, the regulation causes the voltage to rise to high values in an attempt to maintain the current at this constant value. Should such a circuit be closed through the exposed line and fuse burn out the automatic regulation would build the voltage up to such a value as to maintain an arc across the gap. This would be a serious fire hazard. If the drop wire is very long, air-gap protectors may also be attached to the line at the cable terminal, otherwise the protection will be placed only at the station end of the drop wire.

19. Drop wire.—Connection must be made from the station protector to the cable or open wire line connected with the office. Leaving the open wire until a later discussion, it will be assumed that there is available a cable connected with the office. From the station protector the drop wire is run to a convenient cable pole. This drop wire consists of two copper conductors insulated from each other. A common type of drop wire has the conductors parallel to each other and a protective braid around the pair. Other types are twisted with individual braid over the insulation of each wire. The drop wire with its protective covering is designed to withstand exposure to the weather, and have good tensile strength as well as good conductivity.

20. Cable distribution.—At intervals along the cable there will be located cable terminal boxes. These terminals contain 10, 16, 26, or more pairs which are spliced into the cable in multiple with certain pairs in the cable. One pair in the cable may have connections brought out in several terminals. Another pair may have connections brought out in some of the same terminals that the first pair used and in addition some other terminals not used by the first pair. Each pair in a cable is numbered and a record is kept, and sometimes marked on the terminal. One terminal may have pairs 50 to 59 brought out in it while a second terminal may carry numbers 53 to 62 and a third 56 to 71, etc.

a. This plan is used for several reasons. It is impossible to tell in advance over a period of years how many telephone circuits are going to be required in the neighborhood of one terminal as compared with another terminal. Thus, a pair which might be idle if brought out to only one terminal, could readily be used if brought out in a second terminal also. This provides for greater flexibility.

21. Composition of cable.—The cables themselves may be made up of several diffierent size copper conductors, 19, 22, and 24 gage being the most common with 16 and 26 being used in some cases. There may be as many as 1818 or more pairs in a cable. These may be separated into groups of a hundred with all groups bound within the same sheath, or the pairs may be placed in layers from the center out with each layer twisting about the core in different directions. Some cables have each conductor wrapped in paper tape while others, particularly those using the smaller conductors, have the paper pulp molded on the wire. In each pair the conductors are twisted together after the insulation has been placed on the wires.

22. Open wire loops.—Occasionally, the subscriber loop will include a section of open wire construction. Here the drop wire is connected to a pair of open wires, the other end of which may connect into a cable with air gap protector blocks on the circuit at

that point. The drop wire may, of course, be connected to the open wire at any pole. The open wire, usually bare and tied to glass insulators mounted on poles, may be of several sizes. Generally iron wire is used in subscriber loops, due to lower cost as compared to copper, having diameters of .083, .109, and .134 inch. Occasionally copper wire is used in which case .080 and .104 inch wire are most common. The larger the conductor, the less will be the loss through it, though the cost will be higher. Copper wire, of course, costs more than the iron but has much less loss.

23. Questions for self-examination.—

1. What is meant by a "subscriber loop"?
2. Of what does the station protector usually consist?
3. Of what are the air-gap protectors composed?
4. What is the function of the air-gap protector?
5. How much current will the station protector fuses pass without blowing out?
6. Since the telephone voice currents are so very small why not use fuses rated at one ampere instead of higher rating?
7. For what is drop wire used?
8. When are protectors placed at both ends of the drop wire?
9. Why are cable pairs brought out to more than one terminal?
10. What gages of wire are most common in cables?
11. What methods are employed in insulating the wires of a pair in a cable?
12. Where are protectors located when open wire is used in the subscriber loop?
13. What sizes of wire are most common in open wire subscriber loop construction?
14. Compare advantages and disadvantages of copper and iron wire.

SECTION V
TELEPHONE RELAYS

24. Definition.—In the simplest telephone systems all switching is done by the operator. As the telephone system becomes more complex the switching needs, as well as other requirements, make the use of relays necessary. Relays are electrically operated switches or keys and are widely used in the telephone plant.

25. Application.—There are several thousand types of relays which are classified according to their mechanical construction features, number of windings, resistance of windings, number and kinds of contacts, whether contacts are made, broken or switched, the order in which they operate, speed of operation, and current values required for operation. They may be used in control, signalling, supervision, or switching operations. The individual applications are as numerous as are the types of relays manufactured.

26. Construction.—*a. Characteristics.*—The different relays used in the telephone plant vary widely in design and characteristics according to the requirements of the circuit in which they are used. Some relays must operate quickly when energized and remain operated for some time after the circuit has been opened. Others operate slowly and release quickly. The combinations of springs and contacts are practically unlimited. The more precisely timed relays used in dial telephone systems will not be covered in this section. All relays treated in this section consist of an electromagnet, a moveable armature, and a spring and contact assembly.

b. Relay core.—The cores of relays are generally made of some material such as magnetic iron, silicon steel, or permalloy, that will become magnetized when a current passes throught the winding of relay yet will lose its magnetism rapidly when the current ceases to flow. The core must also be strong enough to function as a part of the frame of the relay and withstand the winding operation. Certain types of relays have laminated cores to increase the impedance of the relay windings to voice currents. These relays may be bridged across the talking circuit without greatly increasing the transmission loss. The shape of the relay core, in most cases, is a compromise between production cost and operating efficiency.

c. Armatures.—The magnetic path of any relay will be so constructed as to provide a low reluctance path for the operating flux but will have some arrangement to prevent the armature from actually touching the core and so completing a path through magnetic material for the operating flux. This consideration is important as it allows the rapid demagnetization of the relay when the current in the winding ceases to flow. This gap may be established by a small disk of non-magnetic material, referred to as "non-freezing disk", attached to either the core or armature, or may be adjusted by means of a residual screw in either the core or the armature. The travel of the armature depends upon several factors. A relay for use in a circuit where large currents are available to operate it can have a large unoperated gap and is not likely to be affected by small extraneous currents; a relay that must operate on small currents must have a small unoperated gap and so can not move springs a great distance.

d. Windings.—The winding is applied in evenly wound layers separated by a layer of thin insulating paper that keeps the winding even and so uses the available space more efficiently and also allows the use of less insulation on the wire, as the voltage drop across adjacent turns in the coil will be small. The insulation is usually enamel occupying very little space and is impervious to moisture. It will also stand up under higher temperatures without charring than will silk or cotton when overloaded. The winding or windings of a relay are arranged to meet the requirements of the circuit in which it is designed to operate (fig. 16). Many relays are wound with one of the windings noninductive. This winding is generally wound with half of the turns wound in one direction and the other half wound in the other direction. These relays are used in circuits where voice currents are present. The resistance of the noninductive winding is great enough to cause most of the direct current to pass through the operating winding while the high impedance of the operating winding to voice currents causes them to be bypassed through the noninductive winding. The relay may be wound with two separate coils, or concentrically with one coil wound on the top

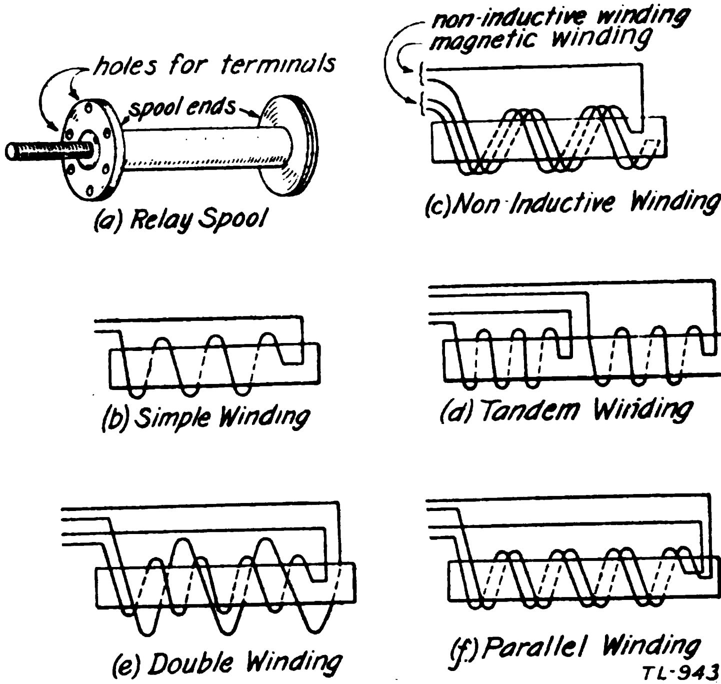

FIGURE 16.—Relay windings.

of the other, or with the two wires being wound on the core at the same time, but the important thing that should be kept in mind is that the same number of ampere-turns are required to operate a given relay regardless of the voltage available. It may be wound with a few turns of large wire to handle large currents or a great many turns of fine wire to operate from small currents.

e. Contacts.—When the armature of a relay moves from the unoperated to the operated position, contact springs are moved so as to open or close one or more circuits. The combinations of springs in a relay are practically unlimited. The only limit to the complexity of the combination lies in the power available to move the armature and so move the moveable contact springs. In relays having flexible contact springs the springs are constructed, and should be adjusted, so that the movement of the armature that causes the contacts to close is continued for a short distance. This continued movement of the contacts after they are closed causes a wiping action between the contacts which tend to make the contacts self-cleaning. In certain new types of relays the springs are split. This splitting of the springs and placing a contact on each half enables the contacts to function normally even if one of the pairs of contacts gets dirty. This reduces the chance of trouble due to dirty contacts to about one-fourth. Some of the simpler arrangements of contacts and their symbols are shown in figure 17.

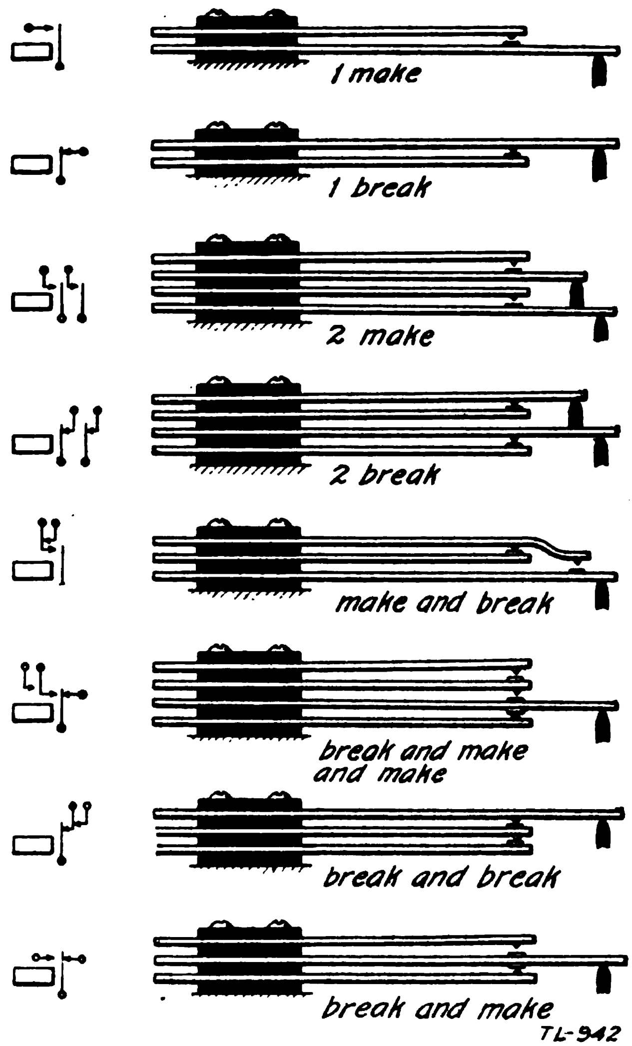

FIGURE 17.—Relay contacts.

f. Relay covers.—The covers of relays normally serve only to protect the relay from dirt and mechanical injury. Most relay covers are made of non-magnetic material so that they do not affect the operation of the relay, and may cover one or more relays. Relays having their windings in a talking circuit, and sensitive relays, have covers made of heavier magnetic material to shield the relay from stray magnetic fields. Because the magnetic force operating a relay may be affected by the shield of magnetic material, relays having covers that act as shields must be adjusted with the covers in place.

27. Marginal relays.—In referring to relays according to their manner of operation there are many different types. One of the most common is the marginal relay. For marginal operation, it is necessary to know both the operate, the nonoperate, and the release values of the relay current and to take advantage of them in arranging the circuit. A marginal relay will pull up when the current reaches a certain "operate" value, and will fall back and remain non-operated as soon as the current falls off to a certain "release" value, less than the operating value. It will not operate on the "nonoperate" value of current.

28. Polarized relays.—Relays designed to operate on current in one direction and remain non-operated on current in the opposite direction are called polarized relays. Polarized relays usually have a permanent magnet which exerts a force upon the armature. This permanent magnet is either aided (for operated relay) or opposed (for the nonoperated position) by the flux set up by the operating windings of the relay, depending upon the direction of the current through the winding. In some relays the permanent magnet is replaced by another winding acting in its place.

29. Slow acting relays.—Some circuits require a relay to be slow to operate, slow to release, or both. Usually these relays are used to obtain a certain sequence of operation in the circuit or to obtain a time interval in the circuit operation. This may be accomplished by proper adjustment of spring tensions, contact arrangements, air gap, or current in the relay windings. Another method is to use a very thick copper sleeve or slug around the core to act as a short-circuited one-turn winding. This is used extensively to make a relay slow acting. Generally the sleeve is placed on the armature end of the relay to make it slow to operate and on the heel end to make it slow to release. However, a relay using a sleeve for making it slow to operate will also be slow to release. Figures 18 and 19 show views of slow operating and slow releasing relays. When slower action in required than can be obtained by the methods outlined

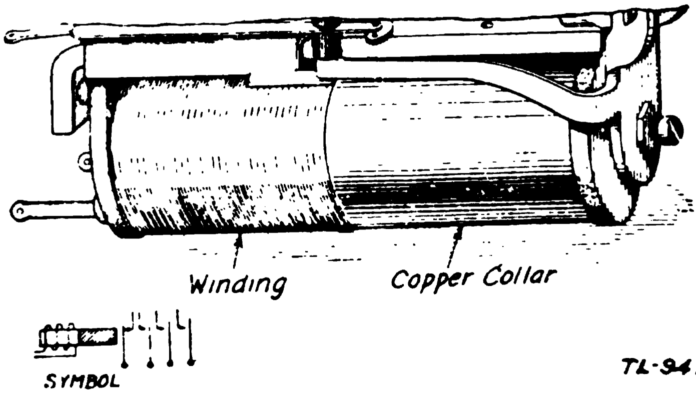

FIGURE 18.—Slow operating relay.

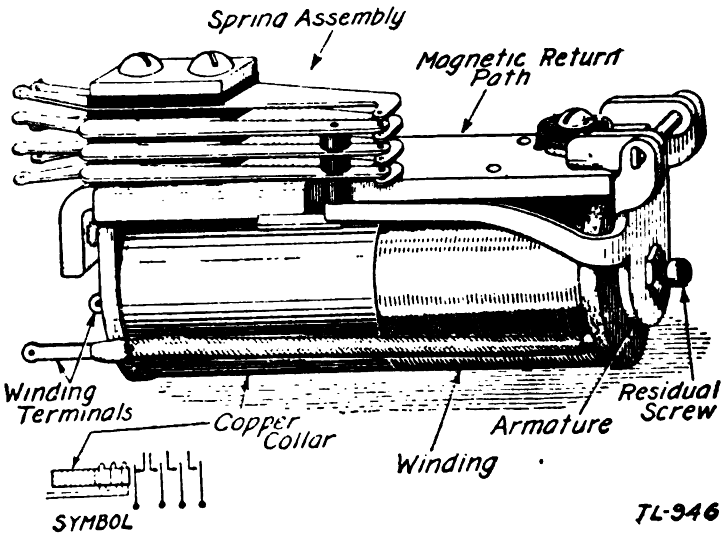

FIGURE 19.—Slow releasing relay.

above, a dash pot relay may be used. In a dash pot relay the armature also operates a piston in a cylinder filled with oil and the oil is forced through a small adjustable hole. The viscosity of the oil and the area of the hole govern the speed of operation.

30. Alternating-current relays.—The relays so far considered in this section have been designed to operate on direct current. Relays that must operate on alternating current must have some provision for holding the armature in the operated position while the alternating current passes through zero every half cycle. The most commonly used type of alternating current relay has the pole piece split and one-half of the pole piece is surrounded by a copper sleeve which acts as a one-turn short-circuited winding. This sleeve acts as the secondary of a transformer inasmuch as a current is induced in this winding. The zero value of this current does not come at the same time as the zero value of the operating current so that there is always enough magnetic force to hold the relay in the operated position. The same results may be obtained by using an armature with sufficient mass that it has enough inertia to prevent it from releasing as the current passes zero. Another method is the use of two windings on separate cores but both affecting the armature. The windings are connected into the circuit so that the current in one winding is out of phase with the current in the other winding.

31. Questions for self-examination.—

1. What is a relay?
2. Upon what basis may relays be classified?
3. What are the component parts of a relay?
4. What types of materials are used in the construction of relay cores?
5. Name three types of windings that may be used on a relay.
6. What limits the combinations of contacts that may be used on a relay?
7. Why are the contact springs adjusted so that there will be a continued movement of the armature after the contacts have been closed?
8. What are marginal relays? Polarized relays?
9. How may a relay be made to be slow acting?
10. How are alternating-current relays constructed?

SECTION VI
COMMON-BATTERY LINE CIRCUITS

32. Line jacks.—At a common-battery exchange each of the subscriber lines is connected to the springs of a jack on the switchboard. This is the same as in local-battery practice, except that the jack has one more contact. The contacts of a local-battery jack are tip and sleeve, while those of the common-battery jack are tip, ring, and sleeve. The tip and ring contacts are springs and the sleeve contact is tubular. See figure 20 which illustrates both simple and cut-

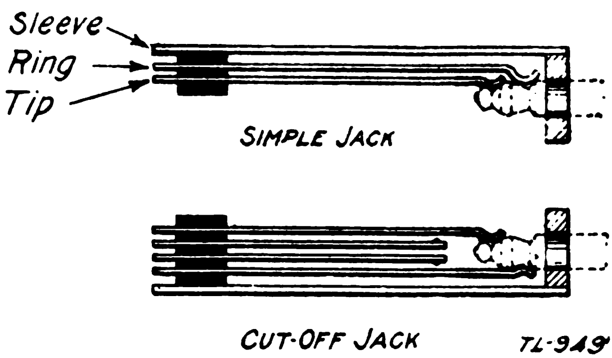

FIGURE 20.—Line jacks.

off jacks. Tip and ring springs in common-battery switchboards afford connection for the line, and the sleeve contact affords connection to certain auxiliary circuits. The simple jack is used when cut-off of signaling apparatus is not required or when cut-off is effected by relays; the cut-off jack is used when the cut-off is mechanical. Jacks are made in strips of ten or twenty, according to the switchboard in which used.

33. Line signals.—In a common-battery switchboard the line signal is usually a small lamp instead of a drop. This lamp is constructed as shown in figure 21. It has a small wooden block cemented to the end to support and insulate the filament terminals which are small metal plates extending along opposite sides of the tubular lamp bulb. These lamps are inserted in simple two-conductor jacks,

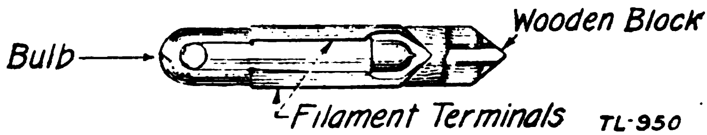

FIGURE 21.—Signal lamp.

known as lamp jacks, as shown in figure 22 and the mouth of the jack is closed with a glass lamp cap which may be one of a number of colors or markings to designate the class of service given the line, a matter which will be discussed later. Lamp jacks, too, are built in

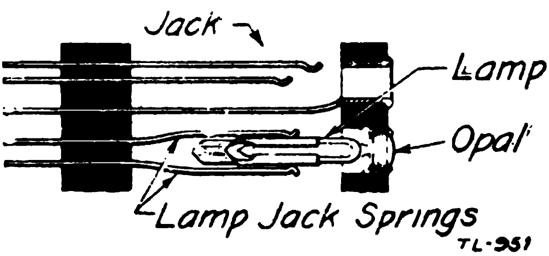

FIGURE 22.—Lamp jacks.

strips of ten or twenty and in the switchboard are mounted either directly above or below the line jacks with which they are associated.

34. Hookswitch control of signal.—The terminal voltage of the exchange battery is available at the hookswitch contacts of every idle telephone in a common-battery system. When a person desires to place a call, he removes the hand-set from the cradle, permitting current to flow from ground through the tip springs of the jack, the tip side of the line, the telephone, the ring side of the line, the ring springs of the jack, the line lamp, the battery and back to ground. This causes the lamp to light. A simple circuit by which this is accomplished is illustrated in figure 23. The battery shown in the diagram is the 24-volt exchange battery, *the positive side of which is*

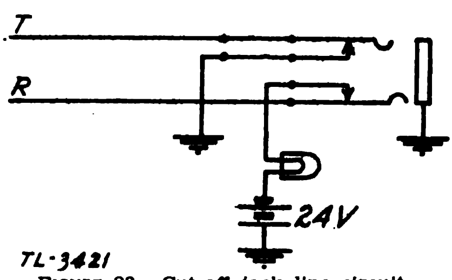

FIGURE 23.—Cut-off jack line circuit.

permanently grounded. This circuit is used exclusively in small switchboards which are designed to serve short lines of approximately equal length. The merit of the circuit lies in its simplicity

and low cost. Its disadvantages are that the jack cut-off springs are not easily adjusted, because of their inaccessibility, and that it requires different kinds of lamps for different lengths of lines. The current in a lamp is governed by the resistance of the line with which it is associated. If the lamp designed for a long line were used on a very short line, the lower resistance of the line would cause such a heavy current to flow that the lamp would have a short life. Obviously, lamps of different operating current and requiring different voltages to light them are required. Such lamps are commercially available. For example, Western Electric "code 2" lamps are made in types ranging from the 2A requiring .17 to .21 amperes at 4 volts to the 2T requiring .025 to .035 amperes at 35 to 47 volts. A multiplicity of types of lamps on a switchboard, with the chance of getting the wrong type lamp associated with a line, complicates maintenance and is to be avoided. The Western Electric lamp code No. B2, rated at 18 volts and .036 to .048 amperes, is used on the switchboard BD-89. The current ranges of these lamps are suitable for the differences in length of lines usually connected to these switchboards. The line lamp of the BD-89 is protected by a varistor in parallel with the lamp as shown in figure 24. The varistor consists of two silicon-carbide discs. The resistance of the varistor is high at 24 volts and therefore does not materially affect the light-

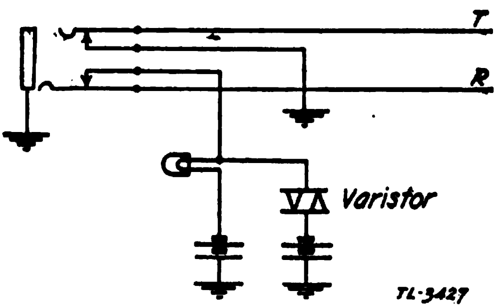

FIGURE 24.—Varistor protected line lamp.

ing of the lamp. When voltages higher than normal are induced in or connected to the line, the resistance of the varistor decreases, thus bypassing the excess current around the lamp.

35. Line circuit with line relay.—The circuit shown in figure 25 places a single wound relay (with one make contact) in series with the battery and has a local circuit controlled by the relay to light the lamp. This circuit requires only one type of lamp since the lamp circuit is entirely independent of the line. The margin of current

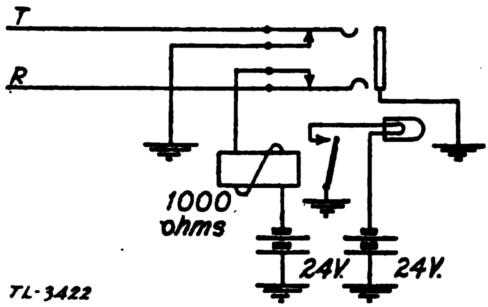

FIGURE 25.—Line circuit with line relay.

between that required to operate a relay and that which would burn out the winding can be made very large; hence, different types of relays are not required for different lengths of line.

36. Representing battery in diagrams.—It will be noted that there are five ground connections and two batteries shown in the figure 25, and this would seem to complicate the wiring of the circuit. As a matter of fact there is only one battery and one battery ground in the usual switchboard. The ground is connected to the positive terminal of the battery. In schematic diagrams it is common practice to show the negative terminal of a battery directly connected to each point which is wired to a lead to the negative terminal of the exchange battery, and to show a ground connection for each point which is wired to a lead to the positive terminal of the exchange battery.

37. Cut-off relay.—In both of the line circuits shown the jack cut-off springs enable the operator to open the lamp circuit and take battery off the line by the mechanical operation of inserting a plug in the line jack. This is a simple and inexpensive arrangement, but has the disadvantage that the whole strip of jacks must be removed for servicing, thus interfering with the operator. To obviate the necessity for the use of cut-off jacks, the circuit shown in figure 26 was developed. The circuit requires an additional relay, known as the cut-off relay, but it has the advantages that; the jacks are used solely for contact with the plug, the cut-off springs are on the relay, adjustment of contact springs is easily made and the

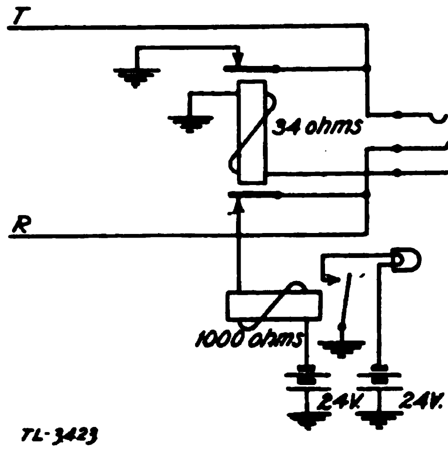

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FIGURE 26.—Line circuit with cut-off relay.

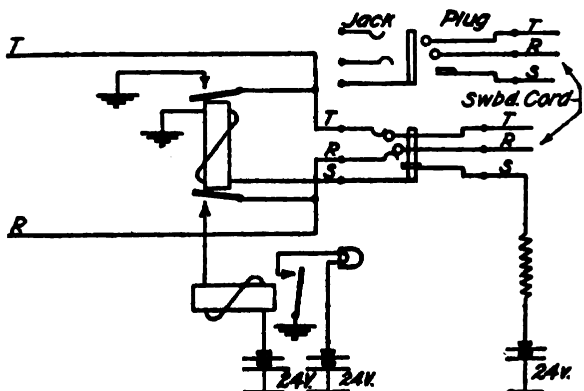

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FIGURE 27.—Line circuit with plug in jack.

making of this adjustment does not interfere with the work of the operator. The cut-off relay is connected between the sleeve contact of the jack and ground. The line relay circuit is the same as with the cut-off jack, except that in this case it goes to the cut-off springs of the cut-off relay instead of to those of the jack; the operation of the line relay and lamp circuits is the same in both cases. However, in this circuit the insertion of the plug simply makes contact to tip, ring, and sleeve, of the jack. The sleeve contact of the plug is one end of a circuit which terminates as the negative pole of the battery, and when the plug is inserted in the jack, current flows to ground through this circuit and the cut-off relay, operating the relay and its cut-off springs. This removes battery and ground

from the line and opens the line relay circuit which in turn opens the lamp circuit, extinguishing the line lamp as shown in figure 27.

Before the cut-off relay operates, the line may be noisy due to

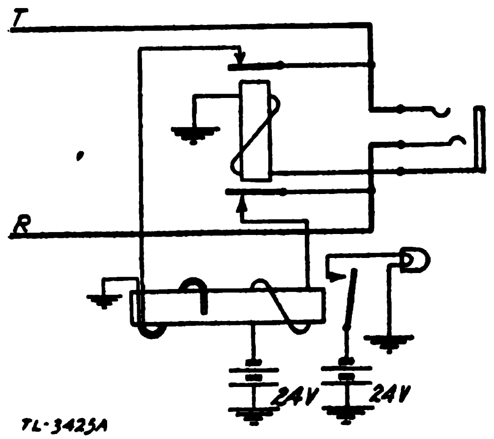


FIGURE 28.—Line circuit with double-wound line relay.

currents from line to ground. As may be seen from figure 26, voltages induced in the line by currents in a nearby line will cause current to flow to ground through the cut-off relay springs. The high resistance of the line relay will cause that part of the current on the ring side of the line to flow through the low resistance of the telephone to the tip side of the line and back through the relay springs to ground. A resistance, equal to that of the line relay, added between tip and ground will cause this current to divide equally to ground and not flow through the telephone. For a convenient place to mount the resistance, the line relay in this circuit is usually a double wound relay as shown in figure 28. The winding furnishing resistance to ground is a noninductive winding.

38. Long lines.—By a slight variation as shown in figure 29 the line circuit can be arranged for use on lines where the loops are too long for satisfactory common-battery operation. To prevent noise from leakage currents, no battery is connected to the line after the cord is plugged in. It is operated with a local-battery telephone.

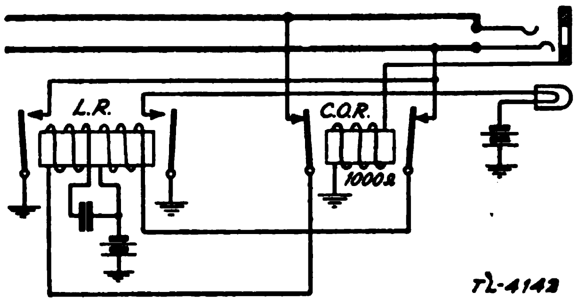


FIGURE 29.—Line circuit with ring-up line relay.

When it is desired to place a call, ringing current is put on the line. This current passes through the condenser so that the two windings on the line relay are in series and it closes its contacts. Current flows from ground through the left contact of the *LR* relay, through a contact on the cut-off relay, through one-half of the line relay winding, to battery and holds this relay operated after ringing current has stopped. Current flows through the other contact of the *LR* relay and lights the line lamp. When the plug is inserted into the jack, battery is placed on the cut-off relay. This removes the line relay from the line and opens the holding circuit which opens the lamp circuit and clears the line. The resistance of the cut-off relay is high enough to prevent operation of the cord circuit relay and no battery is fed to the line when the proper cord circuit is used.

39. Types of line circuits.—In summation, there are three types of common-battery line circuits. The first is the line circuit with cut-off jack and without line relay. It is used in small switchboards where the lines are short and of nearly uniform length. It is also found in army switchboards where the shock and vibration of transportation and the space required makes relays undesirable. The second is the one with cut-off jack and line relay. It is used in small switchboards and some larger switchboards where the lines are of unequal length and the load is not so heavy as to make maintenance of contacts and cut-off springs from the front of the board objectionable. The third is the line and cut-off relay type, which is used in all of the larger switchboards designed for serving the maximum load. The fourth circuit discussed is not a common-battery line circuit. It is an adaptation for connecting local-battery lines to a common-battery switchboard where the lines are too long for common-battery operation.

40. Line lamps and jacks.—It has been brought out that common-battery line jacks are three conductor jacks of either the cut-off or simple type. The connections are tip, ring, and sleeve. Line is connected to tip and ring and the sleeve is grounded. The switchboard

apparatus of the line circuit is usually connected with ground on the tip and battery, through associated apparatus, on the ring. The line signals of common-battery switchboards are lamps and they are mounted in jacks and behind lamp caps in strips directly above or below the strips of line jacks so that each line lamp is adjacent to the jack of the line which it represents. Line lamps are available with various current and voltage characteristics.

41. Questions for self-examination.—

1. In what respect does a common-battery jack differ from a local-battery jack?
2. What kind of line signals are used on a common-battery switchboard?
3. What is necessary for the subscriber to do in order to bring in a signal on a common-battery switchboard?
4. Draw a diagram of a telephone connected to a line circuit which contains no relays.
5. What is the disadvantage of having the line lamp in series with the line as it is in the above diagram?
6. Name the three contacts on a common-battery line jack.
7. Draw a diagram of a line circuit containing a line relay and a cut-off jack.
8. What is the disadvantage of using cut-off jacks in line circuits?
9. Draw a diagram of a line circuit which overcomes this disadvantage by using a cut-off relay.
10. In answering the following refer to figure 28. Line relay coil $=1000\omega$, noninductive coil$=1000\omega$, cut-off relay coil$=37\omega$, lamp$=240\omega$. Operating values of relays, cut-off—.047 amperes, line—.0058 amperes.

a. What would be the effect of a cross between sleeve and ring?

b. Would the line lamp light if battery were placed on the tip?

c. Would the cut-off relay operate if ground were placed on the ring?

d. If the sleeve and lamp wires were crossed, how would the circuit be affected?

e. If the sleeve were crossed with the sleeve of another circuit, how would the operation of this circuit be affected when the other circuit was in use?

f. If the ring were crossed with the tip of another circuit, how would the trouble be indicated?

SECTION VII
COMMON-BATTERY CORD CIRCUITS

42. Description of cords and plugs.—The cord circuits of common-battery switchboards are fundamentally the same as those used in local-battery switchboards. However, there are many points of difference which are due to the centralization of the battery supply and to the automatic and continuous supervision. It has been noted that there is a difference in the jacks of the line circuits. This calls for corresponding differences in the cords and plugs. The cords of common-battery switchboards are of three conductors, instead of

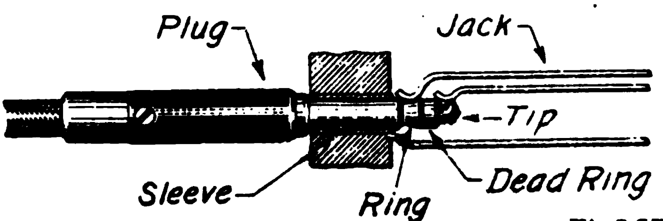
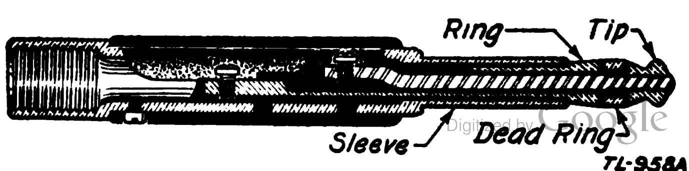


FIGURE 30.—Common-battery plug and jack.

two, and the plugs have three contact elements. Figure 30 shows a common-battery plug inserted in a jack. Observe the tip, ring, and sleeve making connection with the corresponding springs of the jack and note that there is a second ring of metal between the tip and the ring. This is called the dead ring and is required to reinforce the insulaton where it is increased in diameter to prevent possibility of short-circuiting the tip and ring contacts of the plug. Figure 31 shows a cross section of a common-battery plug.



43. Battery feed—battery bridged across line.—Perhaps the best way to understand just how a cord circuit functions in a common-battery board is to build up a circuit in a logical manner. This cord circuit must perform several functions, and in the common-battery system it must, in addition to all other functions, furnish current for talking purposes to every telephone in the system. This current must be furnished over the tip and ring of each plug since the pair of wires from the telephone is connected to the tip and ring of the jack. First, consider just the tip and ring conductors of the cord circuit and see how the 24-volt central office battery can be connected to them. The simplest way is to connect the battery

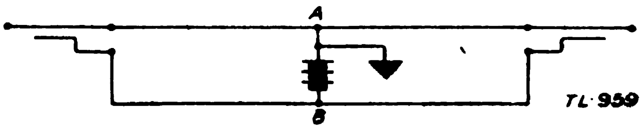


FIGURE 32.—Simplest common-battery cord circuit.

directly across the cord circuit as shown in figure 32. As shown in the diagram the positive side of the battery is always grounded and is the side connected to the tip, while negative battery is connected to ring. This arrangement will not work in practice. The reason for this may be seen by referring to figure 33. This merely shows two telephones connected by such a system of battery feed omitting all other equipment. Assume that (*a*) is speaking. When he talks he varies the direct current flowing through his transmitter. In order that (*b*) hear (*a*), these variations in current

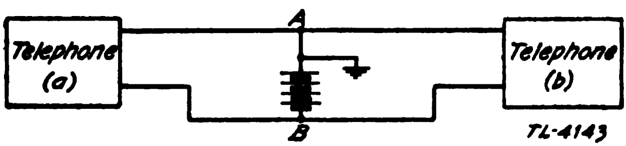


FIGURE 33.—Simple cord connecting telephones.

must reach (*b*)'s telephone. Instead of reaching (*b*) these variations in current pass through battery *AB*, because of the very low internal resistance of the battery. Another way of looking at it might be this. With no one speaking at either end, only direct current from the battery is flowing in both halves of the line. Now as soon as (*a*) speaks the current in his half becomes a pulsating current, or it could be considered as being two currents, a direct current originating at the battery and an alternating current of voice frequency originating at (*a*). So far as the alternating current is concerned the battery is a direct short, so all of it takes the path *AB* rather than the parallel path which is telephone (*b*).

44. Battery feed—retardation coil system.—*a. Single coils.*—To prevent the battery from providing a short circuit to voice frequency currents, an inductance must be put in series with the battery so that a high impedance is offered to alternating current and a low resistance to direct current. In telephone practice this inductance is called a retardation coil. In order to keep the line balanced the retardation coil is divided in two parts, one part in series with each battery lead. A cord circuit with a retardation-coil battery feed is shown in figure 34. Coils x and y are wound on the same core. One

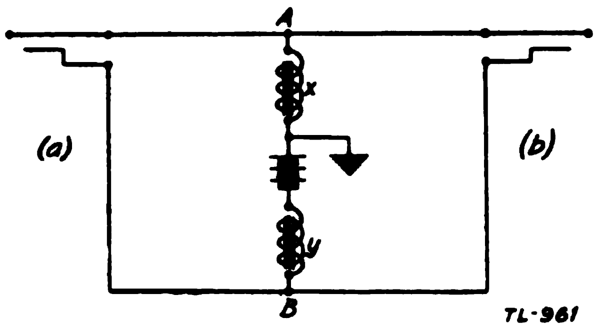


FIGURE 34.—Cord circuit with single retardation coil.

problem in connection with battery feed has been solved but another has been introduced. In figure 33 if the lines to (*a*) and (*b*) are of unequal length, the long line will draw less current than the short one; but it is to be noted that since the battery has very low resistance the current in one line is independent of the resistance of the other line. In figure 34 however, it may be seen that, since the retardation coil must have an appreciable resistance, the *IR* drop in the coil will be due to the current fed to both lines, and the current in one line is affected by the resistance of the other. The direct current flow through a subscriber's transmitter should be the same regardless of the line to which the connection is made.

b. Double coils.—If the battery is connected to each line through separate retardation coils as shown in figure 35, the current in one line is independent of any condition existing on the other half of the cord circuit. The capacitors shown are required to provide a low impedance path for voice currents through the cord circuit. Coils x

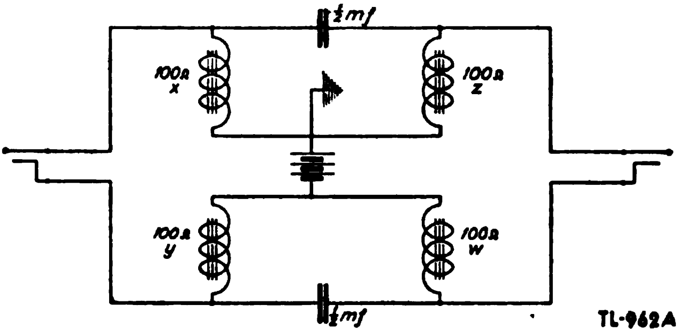


FIGURE 35.—Cord circuit with double retardation coils.

and y are combined on one core; z and w on another core. The resistance of the winding should be high enough to prevent excessive currents from flowing through short lines. A 48-volt system will naturally have higher values of coil resistance than a 24-volt system and this helps to maintain a more uniform direct current to all of its common-battery lines. It is to be remembered, however, that a high resistance line will always draw less transmitter current than a low resistance line. This is not serious if kept within proper limits.

c. Other features.—So far only the method of connecting the battery to the cord circuit has been considered. The cord circuit must accomplish several other things, too. The operator must have a means of talking with the subscribers, of signaling them, and also a means of supervision.

45. The operator's telephone—sidetone circuit.—The receiver circuit of the operator's set is placed directly across the cord circuit by means of a listening key just as in a local-battery cord circuit. The cord circuit with operator's set added is shown in figure 36. The receiver circuit is the same as a local-battery receiver circuit, except that it contains a capacitor. This capacitor opens the circuit to direct current, making it unnecessary to pole the receiver. It also insures proper supervision as will be seen later. The central-office battery is used in the primary or transmitter circuit. A high resistance choke is in series with the battery. This reduces the trans-

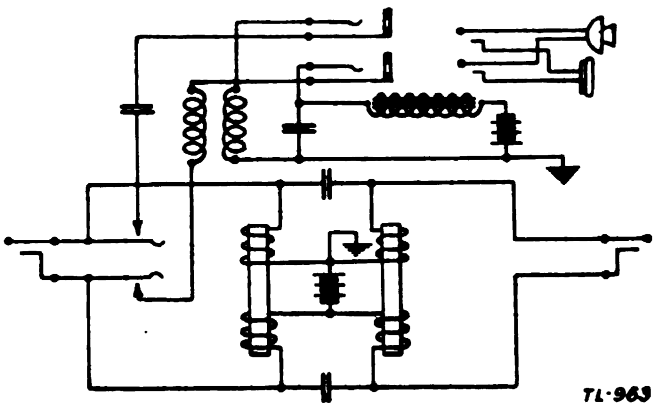


FIGURE 36.—Cord circuit with operator's telephone circuit.

mitter current to the proper value, and also prevents voice pulsations from passing through the battery. The capacitor is in the path provided for the voice frequency currents. The transmitter circuit is closed all the time that the operator's plug is in the jack. This may not always be the case, but it is common practice. Whenever the operator's plug and jack arrangement is used the transmitter is connected to the two tip contacts and the receiver to the two sleeve contacts; consequently it does not matter which way the plug is inserted in the jack. The operator's set shown employs the sidetone telephone circuit.

46. Signaling circuit.—Common-battery cord circuits will always have ringing keys, but usually will not be equipped with ring-back keys. However, the circuit may be equipped for two- and four-party signaling. This will be described later in a separate section. Figure 37 shows a circuit having the ringing key only. In figure 38 the cord circuit has both a ringing and ring-back key. Signaling current may be obtained from a ringing machine, in which case all the operator need do is to operate the ringing key.

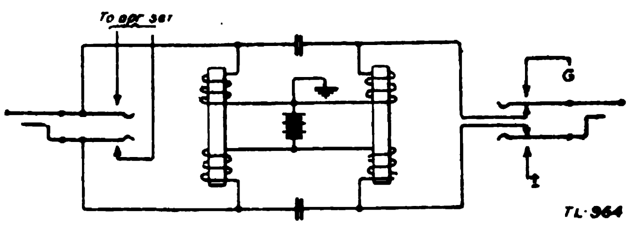


FIGURE 37.—Cord circuit with ringing key.

47. Supervision.—Supervision in a common-battery switchboard is given by two lamps on the plug shelf, one associated with the answering cord and the other with the calling cord. These lamps are extinguished when the hook of the telephone with which they are

associated on a connection is up and they light when the hook is depressed. As soon as a party finishes talking and replaces the handset on the cradle the supervisory lamp associated with this party

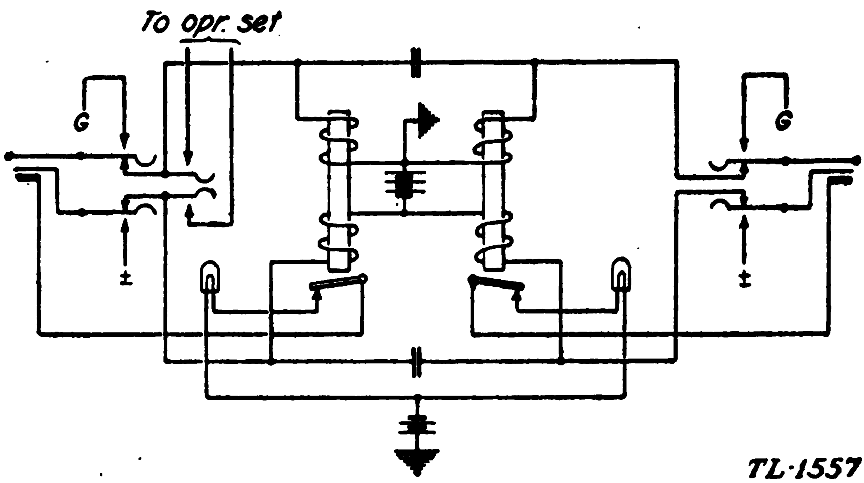


FIGURE 38.—Retardation-coil cord circuit.

lights. This is accomplished by grounding the sleeve of each line jack and placing battery on the sleeve of each plug through the lamp and the contacts of the combined retardation coil and supervisory relay. The cord circuit with this supervisory circuit added is shown in figure 38. In order to effect supervision each retardation coil is a tandem-wound relay with one break contact which is in the sleeve circuit of the cord. If one of the plugs is inserted in the jack of an idle line, current will flow through the sleeve circuit and light the supervisory lamp. Now if the receiver is removed from the hook, current will flow through the retardation-coil winding, causing the sleeve circuit to be opened at the relay contacts and the lamp to go out. If the receiver is replaced on the hook the supervisory lamp will light again. This is known as open-out supervision because it opens the lamp circuit. This retardation-coil cord circuit cannot be used with the cut-off relay type of line circuit, because as soon as the supervisory lamp circuit is opened, current would cease to flow through the cut-off relay which would release and connect ground to one side of the line and battery to the other. On a short loop this would bring in the line lamp giving a false signal. The circuit can, however, be modified slightly, as shown in figure 39, to give correct supervision. Sufficient current is put on the sleeve of the plug to hold the cut-off relay operated, but not enough to materially affect the lighting of the lamp.

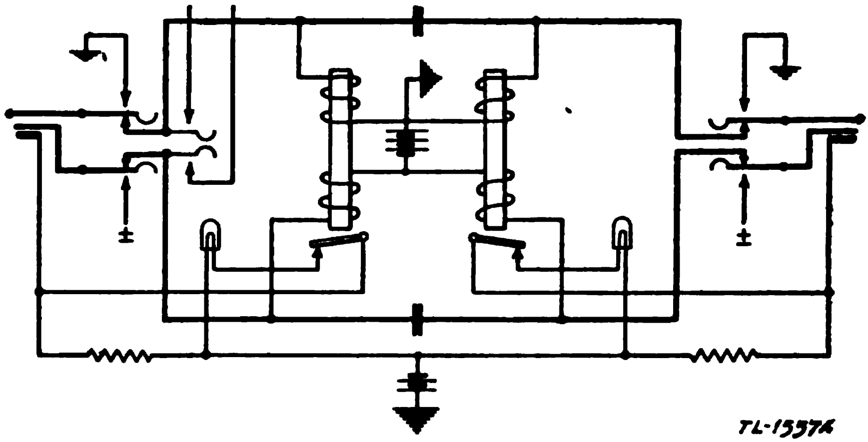


FIGURE 39.—Retardation-coil cord circuit with modified open-out supervision for use with cut-off relay.

Note.—The student should assume that the party on the left desires to place a call, and follow it through, noting just when certain lamps light and go out, when certain relays operate, etc.

48. The repeating coil.—*a. General.*—In nearly all of the large common-battery switchboards, a different type of cord circuit than that previously discussed is used. This is known as the repeating-coil type. Before going into an explanation of the circuit the characteristics of the repeating coil should be understood. A repeating coil is a very efficient one-to-one ratio, four-winding, transformer. The coils used in cord circuits differ somewhat from the repeating coils used for simplex and phantom circuits. The latter coils are efficient transformers of ringing frequency as well as voice frequencies, and are known as ring-through coils. In a cord circuit it is not necessary that the coil used repeat ringing frequency. Such a coil is called a non-ring-through coil, and differs from the simplex or phantom coil in that it has much less iron in the core.

b. Construction.—The core of Western Electric No. 25 repeating coil, which is widely used in cord circuits, is made up by winding a continuous iron wire in the form of a torus. The four windings, each of 21-ohms resistance, are then wound around this core. Figure 40 shows a schematic diagram of this arrangement. Since the core is

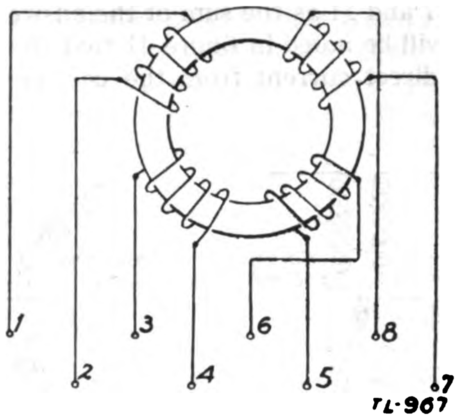


FIGURE 40.—Schematic diagram of a repeating coil.

constructed of one wire wound in the form of helix, air gaps are introduced in the magnetic circuit, preventing saturation. This construction is the equivalent of fine laminations; losses due to eddy currents are thus reduced to a minimum, making the repeating coil a highly efficient transformer over a wide range of voice frequencies. The core and its windings are placed in a pressed steel shell and the shell is filled with insulating compound. In the 25–A coil, two coils are mounted on a single wooden base about eleven by four inches and the ends of the windings brought out to lugs at one end of the base. In the 25–C coil lugs of each coil are at opposite ends. The wiring diagram of the coil is usually stenciled on the housing and the terminal lug numbers are stamped in the wood of the base.

c. *Representation.*—Figure 41 shows the wiring diagram and figure 42 the symbolic representation of the connections to the coil for use in cord circuits. They can be recalled by remembering

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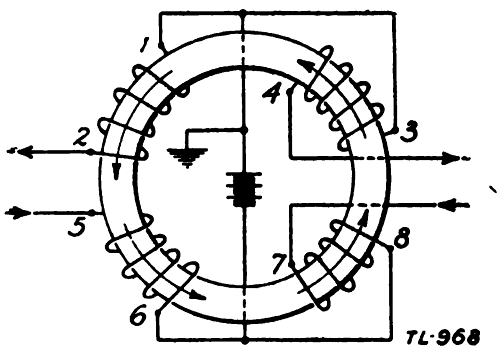

FIGURE 41.—Wiring diagram of a repeating coil for cord circuits.

the numbers 7 and 11 as the sum of the answering and calling cord numbers. It will be noted in figure 41 that the fields induced in the core by the direct current from the battery are all in the same direction.

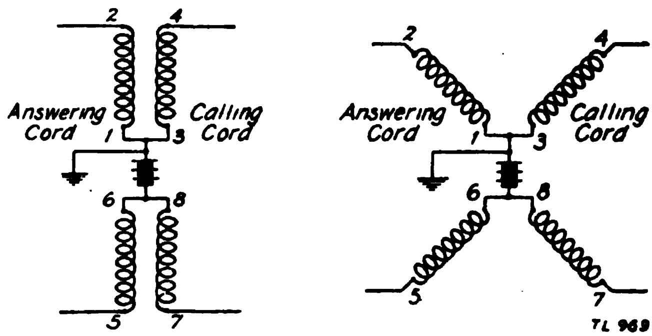

FIGURE 42.—Diagram of repeating coil connections.

49. **Explanation of repeating-coil cord circuit.**—*a. Repeating coil action.*—There are two ways of looking at the action of a repeating coil. Consider the schematic diagram in figure 43. This shows battery being fed to two telephones through a repeating coil just as it is when a connection is made using this type of cord circuit. As long as neither party talks, only direct current flows in each half of the circuit. We may think of the two halves of the circuit as being coupled together by a highly efficient one-to-one transformer. The *1–2* and *5–6* windings in a series make up one transformer winding

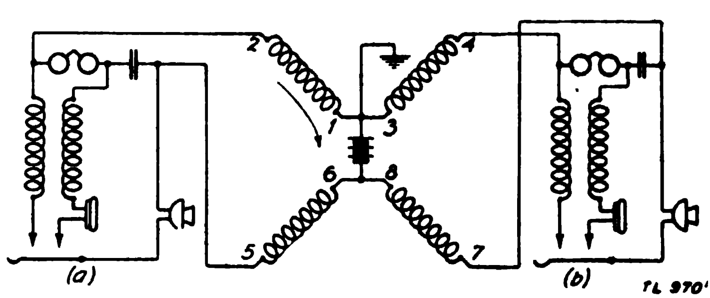

FIGURE 43.—Schematic diagram.

and the *4–3* and *7–8* windings the other. Now assume (*a*) speaks. This causes an alternating current of voice frequency to flow in that half of the circuit. Assume the first pulse of this alternating current to be as shown in figure 43 (down through the battery). Then since this is a one-to-one ratio transformer and very efficient it will induce

an opposite and equal impulse in the other transformer winding. This induced pulse will be up through the battery, hence, the resulting change in current through the battery is zero. Thus the alternating current in one-half of the circuit will cause a corresponding alternating current to flow in the other half, so one party will hear what the other says, yet the current through the battery itself, which is the part that is common to all cord circuits, remains unchanged.

b. Retardation coil action.—There is another way of looking at the action of a repeating coil. By referring to figure 41 it will be noted that the winding *2–1* is so wound with respect to *6–5* that they constitute a retardation coil. Similarly, *3–4* and *7–8* constitute another retardation coil. The effect of each of these coils is to prevent sudden changes in current flowing through them. But considering *1–2* with respect to *3–4*, and *5–6* with respect to *7–8*, each of these pairs combine to form the equivalent of noninductive winding, with no reactance to sudden changes in current. Now assume an impulse originating at telephone (*a*), figure 43. This impulse enters the repeating coil at *2*, but the retardation coil effect prevents it from returning by *5* while the noninductive effect allows it to leave by *4*. It passes through telephone (*b*) and back to *7* where the retard effect prevents it from going to *4*, while the noninductive effect allows it to leave by *5* and back to (*a*) where it originated. This second explanation agrees exactly with that given for the retardation-coil cord circuit. Thus, the repeating coil accomplishes exactly the same thing as was accomplished by use of two retardation coils and two capacitors.

c. Use.—The type of battery feed shown by figure 43 is sometimes called the Hayes system. Figure 44 shows a cord circuit using the Hayes system or repeating coil type of battery feed.

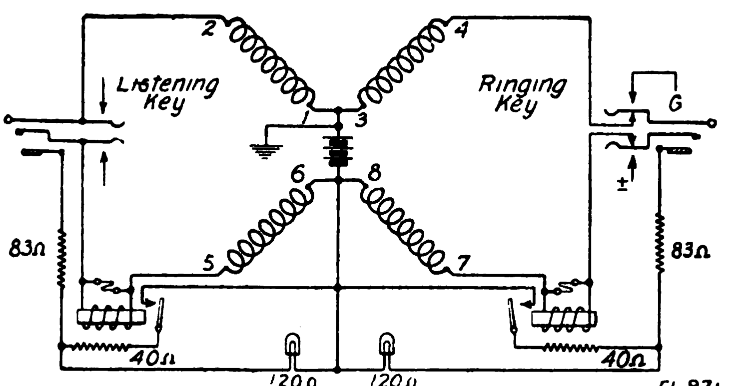

FIGURE 44.—Hayes system of battery feed.

50. Supervision on repeating-coil cord circuit.—It will be noted that the supervision in figure 44 is different from that considered previously. It is not possible to utilize the magnetic field of the repeating coil to operate armatures, hence, separate supervisory relays are required. Since the windings of these relays are in the talking circuit, it is necessary to furnish a bypass for voice frequency currents. This might be done by use of a capacitor, but this has the disadvantage that the reactance of a capacitor varies with the frequency and also this would add another piece of equipment. It is common practice to use a relay with a noninductive winding in shunt with the pull-up winding. The resistance of the noninductive shunt must not be so low as to bypass so much direct current that the relay will not operate. The relay has a make contact instead of a break. In the sleeve circuit there are two parallel branches, one containing the supervisory lamp, and the other the make contact and a 40-ohm resistor. There is an 83-ohm resistor in series with both, the purpose of which is, with the resistance of the cut-off relay of the line circuit, to limit the current through the lamp with the relay contact open. The purpose of the 40-ohm resistor is to reduce the current through the lamp, when the relay operates, to such a value that the lamp will be warm, but will not give off light. This type of supervision is known as the shunt-out type. It has advantages over the open-out type in that the lamp is kept warm and will therefore light to full brilliance in less time; also the sleeve is never opened and therefore, cut-off relay line circuits may be used with it. It can, of course, be used with any type of line circuit. It is also possible to use open-out supervision with a repeating-coil cord circuit, but this is seldom done.

51. Operator's telephone set, antisidetone circuit.—The operator's telephone used on a board equipped with repeating coil circuits may be of the same type already described, but usually it is a little more elaborate in that it uses an antisidetone circuit. A diagram of this operator's set is shown in figure 45. The primary circuit is the same as the one in the operator's set already described, except that the induction coil winding is really two windings in parallel. This causes a considerable increase in the alternating current over what it would be if the two halves of the coil were in series. Hence, a greater electromotive force is induced in the secondary. The important difference between this telephone and that previously studied is the manner of connecting the receiver. The receiver is placed across half of the secondary winding and a noninductive resistance of about 370 ohms. This value of resistance is taken as being that of the average subscriber loop. Assume the case where this resistance R exactly equals the resistance of the subscriber loop. Then

speaking into the operator's transmitter or any noise in the switchboard room will not cause any current to flow through the operator's receiver. This is true because no matter what voltage is in-

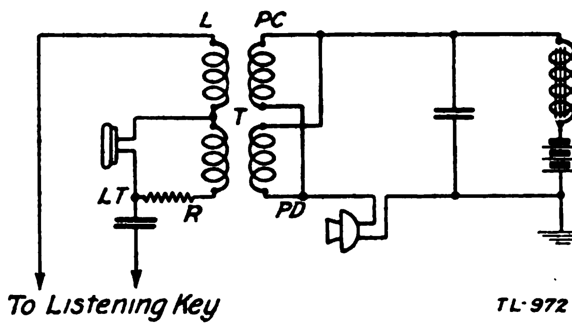

FIGURE 45.—Operator's telephone set.

duced in the secondary, the voltages induced in the two halves are equal and therefore the two receiver terminals are always at the same potential and no current flows through the receiver. This can be more easily understood from figure 46. To make the diagram simpler the voltages induced in the secondary have been shown by batteries. Since $E=E'$ and $R=R'$, the points A and B are always at the same potential. When the subscriber talks, the source of the alternating electromotive force is not the operator's primary circuit, but the subscriber's telephone and for this the operator's

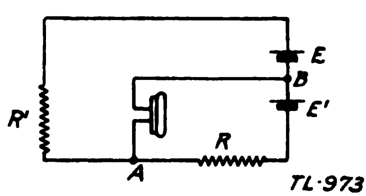

FIGURE 46.—Equivelant antisidetone circuit.

receiver is merely in parallel with half of the coil and R (about 370 ohms). As the resistance of the receiver is considerably below this, most of the alternating current flows through the receiver. This type of operator's set can also be used with the retardation-coil type of cord circuit.

52. Operation of the repeating-coil cord circuit.—Figure 47 shows two substations in an exchange served by a switchboard with repeating-coil cord circuits. Each subset is connected to a cut-off relay type of line circuit. Assuming that one of these subscribers desires to call the other, one may trace on the diagram the operations involved

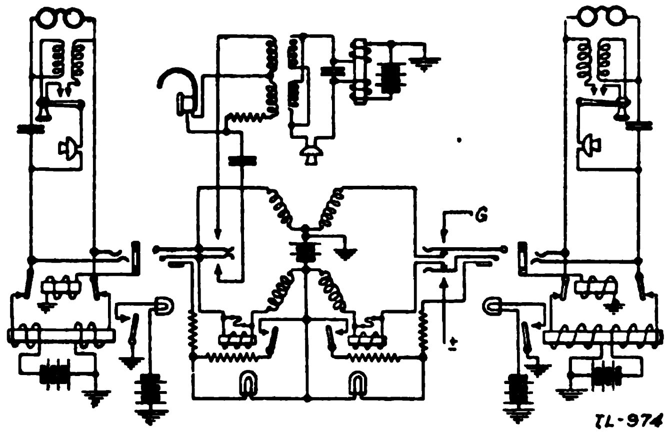

FIGURE 47.—Complete repeating coil cord circuit.

in completing the call, determining just which relays are operated and which lamps are lighted, etc., during each step of the complete operation.

53. Universal cord circuit.—*a. Need.*—On switchboards having both common-battery and local-battery lines it is necessary to have a cord circuit which will supply battery to the common-battery lines and not to the local-battery lines. It must also furnish a talking channel between two subscribers whether either or both lines are common-battery or local-battery. A cord circuit which will do this is called a universal cord circuit. In its usual form a full universal cord circuit uses eight or ten relays in each cord circuit. However, to conserve space and decrease trouble from relays a simplified circuit is used on army switchboards. Figure 48 shows the cord circuit used in the TC-1 and TC-2.

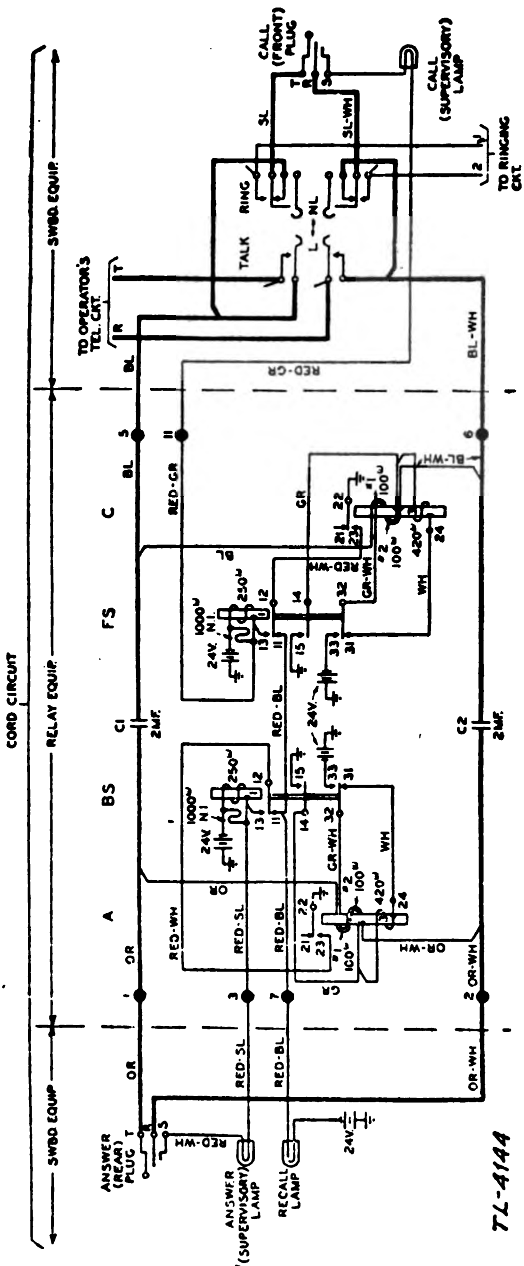

FIGURE 48.—Universal cord circuit.

b. Connection to local-battery lines.—(1) *Incoming calls.*—When the plug of the answering cord is inserted in the jack of a local-battery line circuit the *BS* relay does not operate since the sleeve circuit of the line jack is open. Under this condition the three

windings of the *A* relay are connected series aiding and remain bridged across the tip and ring of the answering cord for ring-off supervision. The operator answers the call with the TALK key in the operated position.

(2) *Outgoing calls.*—When the plug of the calling cord is inserted into a jack of a local-battery line circuit the *FS* relay does not operate since the sleeve circuit of the line jack is open. Under this condition the three windings of the *C* relay are connected series aiding and remain bridged across the tip and ring of the calling cord for ring-off supervision. Upon the operation of the ringing key, ringing current is applied to the line. While the ringing key is not operated, the talking key is operated so that the operator may know when the call is answered at the distant end of the line, since no supervision is obtained when the call is answered.

(3) *Completion of conversation.*—When a conversation is completed, ringing current should be applied to the line by either telephone user in the case of a line-to-line connection or by the distant switchboard operator in case of a switchboard-to-switchboard connection. Ringing current over the line associated with the answering cord operates the *A* relay, and ringing current over the line associated with the calling cord will operate the *C* relay, causing the recall lamp to flash.

c. Connection to common-battery lines.—(1) *Incoming calls.*—When the plug of the answering cord is inserted in the jack of a common-battery line in response to a call, the *BS* relay operates, due to the ground on the line jack sleeve, and the supervisory lamp associated with the answering cord lights. The operation of the *BS* relay connects ground and battery respectively, to the tip and ring of the cord through the No. 1 and No. 2 windings of the *A* relay, thus providing for transmitter battery through the common-battery line circuit. The *A* relay operates since the circuit through its windings is completed at the distant telephone. The operation of the *A* relay short circuits the supervisory lamp, thus extinguishing the lamp by shunt-out supervision. The operator answers the call with the TALK key in the operated position.

(2) *Outgoing coils.*—When the plug of the calling cord is inserted in a common-battery line circuit jack the *FS* relay operates and the associated supervisory lamp lights in series with the *FS* relay. The operation of the *FS* relay connects ground and battery respectively, to the tip and ring of the calling cord through the No. 1 and the No. 2 windings of the *C* relay. Upon the operation of the ringing key, ringing current is applied to the line. When the called telephone answers, the *C* relay operates and shorts circuits the supervisory lamp, thus extinguishing the lamp.

(3) *Completion of conversation.*—When a conversation is completed the parties hang up and the circuit is broken at the telephone hook switch or lever switch in the telephone thus causing the *A* or *C* relay to release which in turn causes the associated supervisory lamp to light. Removal of the plug from the jack releases the *BS* or *FS* relay and extinguishes the supervisory lamp, thereby restoring the circuit to normal.

54. Questions for self-examination.—

1. What additional function must the cord circuit perform in common-battery telephony over those it performed in local-battery telephony?
2. Why is it that a circuit connecting two common-battery telephones with a storage battery only across its center will not give satisfactory transmission from one telephone to the other?
3. Why will not a system of battery feed in which both loops are fed through the same inductance coils work satisfactorily?
4. Draw a diagram of the retardation coil system of battery feed.
5. What is a repeating coil?
6. Explain the action of a repeating coil in a cord circuit.
7. Draw a diagram of the repeating coil system of battery feed.
8. What two keys are associated with each cord circuit?
9. What is the purpose of the two capacitors in the retardation-coil cord circuit?
10. What type of supervision is usually used on a retardation type of cord circuit?
11. What battery is used in the operator's telephone?
12. What is the purpose of the capacitor in the operator's primary circuit?
13. Why is the retardation coil placed in series with the battery?
14. What is the purpose of the capacitor in the operator's secondary circuit?
15. What type of supervision is usually used in the repeating-coil cord circuit?
16. Why is there a noninductive winding on the supervisory relay?
17. What is the purpose of the 40-ohm resistors in the repeating-coil cord circuit?
18. Explain the operation of the antisidetone operator's set.
19. Why is the primary coil split and the two halves placed in parallel?
20. What is the purpose of the resistor in the operator's secondary circuit?
21. What is a universal cord circuit?
22. How is battery fed to the common-battery lines?
23. What are the two principle functions of the *A* relay?
24. What is the function of the *FS* relay?

SECTION VIII
TRUNK CIRCUITS

55. Private branch exchanges.—There is need for interconnection between switchboards, whether they are exchange switchboards or are the smaller switchboards serving business houses, factories, and other plants requiring more than a few telephones. The latter switchboard is known as a private branch or *PBX*. In view of the similarity between the relations of these tributary switchboards to the exchange switchboards and the relations of army post telephone systems to commercial exchanges, the telephone company considers service to army switchboards as *PBX* service. The principal difference between army post systems and *PBX*'s is that the former are usually owned, operated, and maintained by the army, while the latter are rented from the telephone company and are maintained by them; and that where several army posts are close together, they are often interconnected by telephone lines.

56. Problems encountered in trunking.—In developing the circuits for terminating the lines interconnecting switchboards, which are known as trunks, the larger switchboard will be referred to as an exchange switchboard, and the smaller as the *PBX*. The problem in trunking is to provide for signaling and for supervision, without lowering efficiency of transmission and without requiring any departure at the exchange switchboard from the routine in handling service to subscriber lines. Trunk circuits vary in complexity with the conditions which must be met in solving the problem. The circuits on the exchange switchboard, the circuits in the *PBX*, the resistance and length of the trunk line and the nature of the service to be given over the trunk are some of the features causing the wide variety of circuits which are used.

57. Types of trunks.—There are two-way trunks and one-way trunks. The former are equipped with a signal at each end, while the latter have a signal at the switchboard on which they appear as an incoming trunk and have only a jack at the switchboard on which

they appear as an outgoing trunk. Both classes may be automatic or may be ring-down and the two-way trunk may also be automatic one-way and ring-down the other. An automatic trunk is one which will bring in the signal as soon as the distant operator connects to it; and a ring-down trunk is one which requires that the distant operator send out ringing current to bring in the signal.

58. Two-way ring-down trunk.—Figure 49 shows a two-way ring-down trunk with ring-down drops as signals. The capacitors are cut in to avoid giving false supervision due to the bridging of the drop across the distant end of the line before the called switchboard answers. The two sides of the line are reversed so that the batteries at the two switchboards will be in series and not opposing each other. Were the batteries in opposition, no current would flow and there would be no supervision. With the batteries aiding each other, there are certain disadvantages. In the first place, the 48 volts of battery causes twice as much current as that for which the circuit was designed, unless the trunk is longer than the average subscriber loop. This is wasteful of battery energy, may burn out apparatus, and may cause saturation of repeating coil cores. If the grounds are not at the same potential, there will be unbalance of current in the line and this will probably cause noise. Figure 50 shows the method of using that circuit with the lamp type of signal. It is necessary to

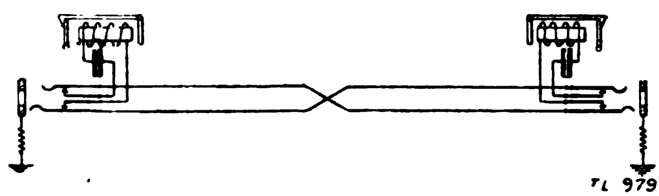

FIGURE 49.—Two-way ring-down trunk with drops.

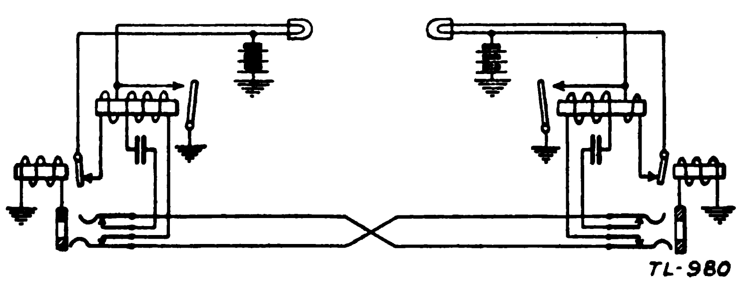

FIGURE 50.—Two-way ring-down trunk with lamps.

provide a holding winding on the lamp relay, and to enable current to reach ground through the sleeve to break the holding circuit. Cut-off relays could be used instead of cut-off jacks in this circuit.

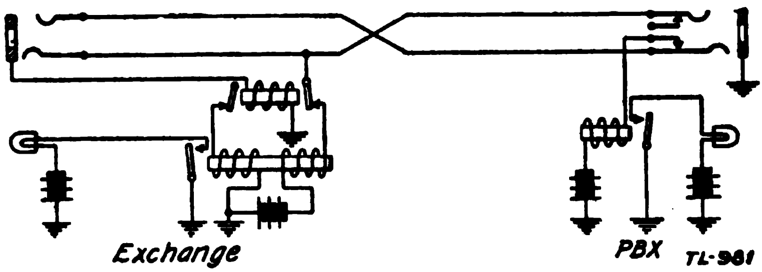

FIGURE 51.—Two-way automatic trunk.

59. Two-way automatic trunk.—Figure 51 shows the circuit of a two-way automatic trunk which is often used as an interposition trunk. As can be seen from the figure it is composed of two line circuits, with the ground removed from the cut-off contact. As shown, one line circuit is of the cut-off relay type and the other of the cut-off jack type, but the arrangement is applicable to any type of line circuit. This should not be used with a retardation coil cord circuit at either end, as it might give improper supervision.

60. One-way automatic, one-way ring-down trunk.—Figure 52 shows a trunk circuit which is automatic one-way and ring-down the other. The equipment at the exchange end is an ordinary line cir-

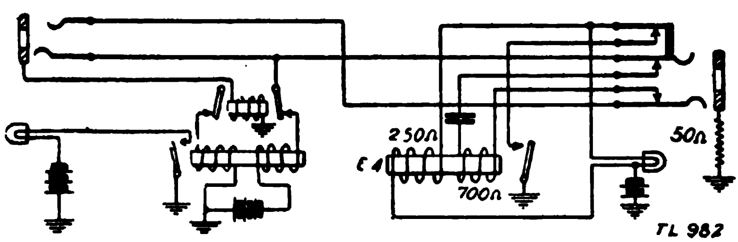

FIGURE 52.—One-way automatic, one-way ring-aown trunk.

cuit. Some army post systems are connected to commercial systems by trunks similar to the above. They are automatic outgoing from the army board and ring-down incoming. The advantage of this lies in the fact that the operation at the commercial exchange end is the same as for a line circuit, and it is possible to group the army post trunks with the commercial subscriber lines. This secures better service than would be obtained if it were necessary to bring them in on a rural or other position; however a repeating coil cord circuit should be used at each end of this trunk.

61. Operation of the trunk.—When the exchange operator plugs in on this trunk to ring, her calling supervisory light comes in because the circuit through the *E-4* relay is open to direct current, due to the capacitor, but when she rings, ringing current passes through the capacitor and relay and rings up the armature. Closing of the relay contact permits current to flow through the relay contact, and

the additional break contact on the jack, to a point where it divides and a portion lights the lamp, and the remainder holds up the relay by action of the 250-ohm holding coil. Thus the ringing brings in the signal and it is held in. When the army operator connects to the jack he opens the cut-off contacts, removing the *E-4* relay and capacitor from across the line and substitutes therefor the tip and ring conductors of his cord circuit; he also opens the additional break contact of the jack which releases the holding winding and opens the lamp circuit. The army exchange battery, poled to assist the exchange battery, closes out supervision at the exchange and holds out supervision at the army switchboard. When the conversation is concluded and the connection taken down at either end, supervision is brought in at the other end because the circuit goes open. When the army exchange initiates a call, the trunk equipment is cut off by plugging in and the line lamp is brought in at the distant exchange, without ringing

62. Repeating-coil trunks.—Every circuit thus far shown requires the proper poling of the circuit for additive connection of the battery and, as explained, there is a circuit unbalance if the grounds are of unequal potential. This inequality of potential may be quite pronounced near cities due to the power and traction systems. To avoid this condition, it is necessary to cut a repeating coil into the trunk circuit, which opens the line and destroys supervision unless some steps are taken to overcome this condition. The principle reason for more or less complex trunk circuits is the necessity for providing for separation of battery and at the same time retaining supervision. Figure 53 illustrates a one-way automatic one-way ring-down trunk circuit which accomplishes this. Before describing the operation of this circuit, the equipment involved in the circuit will be discussed. The jack required is a special jack with one make

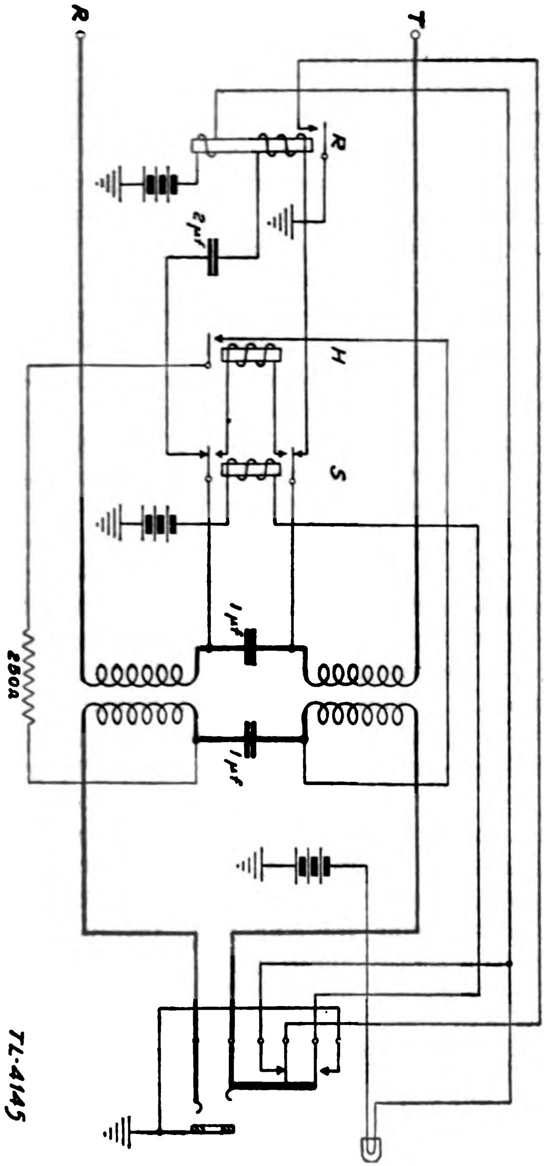

FIGURE 53.—Common-battery repeating coil trunk circuit.

contact and one-break contact. However, a relay with one make contact could be used in the sleeve circuit of the jack to accomplish the same thing if the cord circuit used at the local switchboard has shunt-out or modified open-out supervision. The *R* relay is a ring-down relay with one contact and a double winding. The extra winding acts with the contact to lock the relay in the

operated position. The *H* (holding) relay provides a direct current path through the circuit for current from the distant switchboard and extends supervision to the local switchboard. The *S* (signaling) relay controls the current from the distant switchboard and by opening and closing the direct current circuit at the proper time it extends automatic supervision and signaling to the distant switchboard. The 1μf capacitors between the repeating coils provide a low impedance path for voice currents but offer relatively high impedance to ringing current, consequently ringing current will flow back around through the *R* relay and the 2μf capacitor. The 2μf capacitor opens the ring-down circuit to direct current so that relay *S* will have full control over signaling and supervision to the distant switchboard. When the repeating coil-type trunk circuit is used at the local switchboard it is, in all cases, connected directly to a common-battery line circuit. Under no circumstances should two trunk circuits of this type be connected together at opposite ends of a line.

63. Operation—incoming call.—Refer to figure 53 and assume that a subscriber connected to the distant switchboard desires to call a local subscriber. The distant operator answers the call in the usual way and then inserts the calling plug in the line jack connected through the line to the local trunk circuit and rings. The ringing current causes the *R* relay to operate and close its contact. This contact connects ground to the lamp and the holding winding on the *R* relay. The relay will now remain in the operated position and the signal light will burn until the holding circuit is broken. When the local operator inserts the plug in the trunk jack one contact is broken and another one is made. When the lower contact is broken, ground is removed from the lamp and the holding winding of relay *R*, extinguishing the lamp and allowing the relay to drop back to normal. When the upper contact on the jack makes, a ground connection is placed on the winding of relay *S* causing it to operate. When the *S* relay operates, a direct current path is provided through the *H* relay for current from the distant switchboard; thus the direct current loop is closed and the supervisory lamp on the distant switchboard is extinguished. This same current passing through the *H* relay causes it to operate, closing the local direct current loop through the 250-ohm resistor, and extinguishes the local supervisory lamp. The circuit is now completely set up and the local operator can determine what is wanted and proceed to complete the call.

64. Operation—outgoing call.—When the call originates locally the operation is slightly different. When the local operator plugs into the trunk jack, the make contact places ground on the winding of the *S* relay which operates, closing the direct current loop to the distant switchboard and lighting the line lamp at the distant switch-

board. If the line circuit of the distant switchboard uses a line relay, the current from this source will not operate relay *H* so that the local supervisory lamp will remain lighted until the distant operator places the plug of the cord circuit into the line circuit jack. This will then operate relay *H*, extinguishing the local supervisory lamp and the circuit is ready for the conversation.

65. Supervision.—When the distant operator disconnects from the line, the additional resistance of the line relay reduces the current to a value where the *H* relay will drop back to normal, opening the local direct current loop and causing the local supervisory lamp to light. When the local operator disconnects first, ground is removed from the winding of the S relay, allowing it to drop back to normal, opening the direct current loop to the distant switchboard and causing its supervisory lamp to light.

66. Variation of trunk circuits.—The trunk circuit just discussed is typical of one-way automatic one-way ring-down repeating-coil trunks, which are to be found on many switchboards, but it is subject to many variations and extensions. These variations may run from very complex circuits using six or more relays, to the very simple, using one relay and giving only one-way supervision. It is beyond the scope of this text to include a discussion of these many variations.

67. Questions for self-examination.—

1. What is a PBX?
2. What is a trunk circuit?
3. Explain the difference between a two-way and a one-way trunk.
4. Explain the difference between a ring-down and an automatic trunk.
5. Draw a diagram of a two-way ring-down trunk using drops as signals.
6. Could lamps have been used as signals in the above circuit?
7. Where are two-way automatic trunks often used?
8. Draw a diagram of two line circuits and connect them together to form a two-way automatic trunk.
9. What type of trunk is usually used between a large exchange and a PBX? Why?
10. Why are the tip and ring of the line connecting the two switchboards reversed in a two-way automatic trunk?
11. Is the same type of repeating coil used in the repeating-coil trunk circuit as is used in cord circuits?
12. Refer to fig. 53 for the following questions:

a. What is the purpose of the capacitor in series with the *R* relay?

b. Should it be larger or smaller than the capacitor in series with the repeating coil? Why?

c. Which piece of apparatus, by its operation, puts out the trunk lamp?

d. Explain the operation of this trunk circuit for an out-going call.

e. Explain the operation or the trunk circuit for an incoming call.

f. Which relay is a marginal relay?

g. Why must this relay be marginal?

SECTION IX
SELECTIVE RINGING

68. Party lines.—In army and commercial telephone systems it often becomes necessary, in order to conserve plant facilities, to connect two or more telephones to the same line. Such lines are called party lines. Commercial companies use two- and four-party lines extensively. Such subscribers are given a lower rate, because there are some disadvantages to party line service. If all substations are connected to the line in the ordinary manner and code ringing is used to designate which substation is called, each subscriber on the line must listen every time the bells ring and identify his calling code. Because of code ringing the work of the operator is increased and the subscriber answering time is longer. The frequent ringing of the telephone is annoying and disturbing. Because of the fact that several ringers are bridged across the line, transmission losses are increased. On such a line there is nothing to prevent any of the subscribers from listening to conversations of others. A subscriber on a party line can call or be called only when the line is not in use by other parties.

There are two general methods by which conditions on party lines as outlined above may be improved. The first is by use of a lock-out system and the second is selective signaling.

69. Lock-out systems.—A lock-out system makes the line available to only one subscriber at a time but the means to accomplish this must be complicated. Its cost and maintenance are so great that the saving effected in plant facilities is in general less than the cost of the equipment. For this reason such systems are very seldom used.

70. Selective signaling.—Lock-out systems afford absolute secrecy, but a selective ringing system provides a measure of secrecy by calling only one station without disturbing the others. Selective ringing requires only minor changes in substation equipment, and but little additional equipment at the central office. There are three different methods of selective ringing, namely: ringing to ground, pulsating ringing, and harmonic ringing.

71. Ringing to ground.—*a. Operation.*—This system is used extensively on two-party lines. Figure 54 shows the ringing key part of the cord and the way in which the two subsets are connected to the line for this method of signaling. One of the subsets is connected with L_2 to the tip side of the line and the other with L_2 to the ring side. One side of the ringer of each set, instead of being

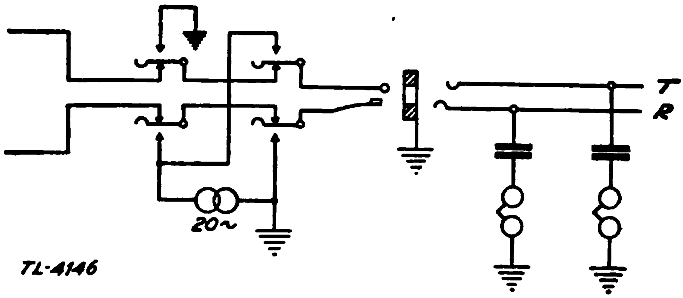

FIGURE 54.—Two-party ringing to ground.

connected to L_1, is connected to the ground terminal which is in turn wired to ground at the protector. At the switchboard, the ringing machine has one side grounded and the other side to the two ringing keys. The keys are arranged so that the one with the red handle will send current out on the tip side of the line, ringing one of the parties, and the one with the black handle will send current out over the ring side and ring the other party. The key with the black handle thrown in the opposite direction is the listening key. In Western Electric switchboards there is a device connected to the two ringing keys to show black when one key is operated and white when the other one is operated. This informs the operator at a glance which key to use to ring the party a second time.

b. Army boards provided with selective ringing.—The army boards BD-80 and BD-89 provide for ringing to ground over either the tip or ring side of the line. Normally the tip side of the line is connected to the grounded side of the 20-cycle supply. By reversing the master ring key the grounded side of the 20-cycle supply is connected to the ring side of the line.

72. Selective ringing with pulsating current.—*a. Biased ringers.*—Before explaining this method of selective ringing it might be well to show how an ordinary 8A ringer can be made to operate on pulsating current. This can be done by biasing the ringer, that is, by attaching a coil spring to one end of the armature as shown in figure 55. Assume the pulsating current to flow in the direction indicated. This current always continues in this direction, but varies in amplitude at regular intervals. Thus the polarity of the electromagnets would always be as shown in figure 55 and the end *A* of the armature would always be attracted and the striker would rest against gong G_2. But by using a biasing spring connected as shown, the tension of this spring can be so adjusted that during the interval when the current is small, the pull of the spring exceeds that of the electromagnets and the striker will hit G_1. The next instant the current

increases and the pull of the electromagnets exceeds that of the spring, causing the striker to hit G_2. Thus it will be seen that by adding this biasing spring and adjusting it, the 8A ringer can be

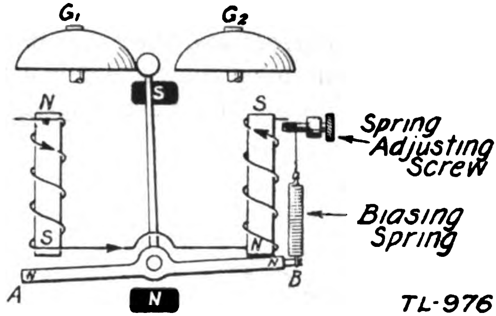

FIGURE 55.—Western Electric Co. 8A ringer.

made to operate on pulsating current.

b. Circuit operation.—Figure 56 illustrates the line and cord circuit arrangements for ringing with pulsating current. In this case both subsets are connected with L_1 to tip and L_2 to ring. Both ringers are biased and are connected between L_1 and ground in each case, but have their terminals interchanged so that one will respond to positive pulsating current and the other to negative. If the ringers were connected between ring and ground on common-battery systems, without a capacitor, direct current would flow from the ring side through the ringer to ground and bring in the line lamp permanently. It is impracticable to ring with pulsating current through a capacitor, so that four-party ringing can be used only on local-battery systems when this method is used.

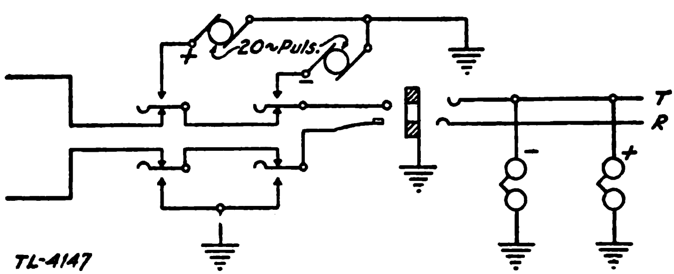

FIGURE 56.—Two-party ringing pulsating current.

73. Four-party selective ringing.—*a. Relays.*—Although four-party selective ringing is seldom seen in an army system it is used a great deal commercially. The four telephones are all connected with L_1 to tip and L_2 to ring. Each telephone contains a relay which is connected between the capacitor and L_1. This relay operates on alternating ringing current and has one make contact. This make contact

is in series with the ringer. All ringers are biased. Two of the ringers are connected between tip and ground, one of these will operate on positive pulsating current and the other on negative. The other two ringers are betwen ring and ground, and one of these will operate on positive pulsating current and the other on negative. Figure 57 shows the way the four telephones are connected and the way ringing current is placed on the line. Each ringing key consists of

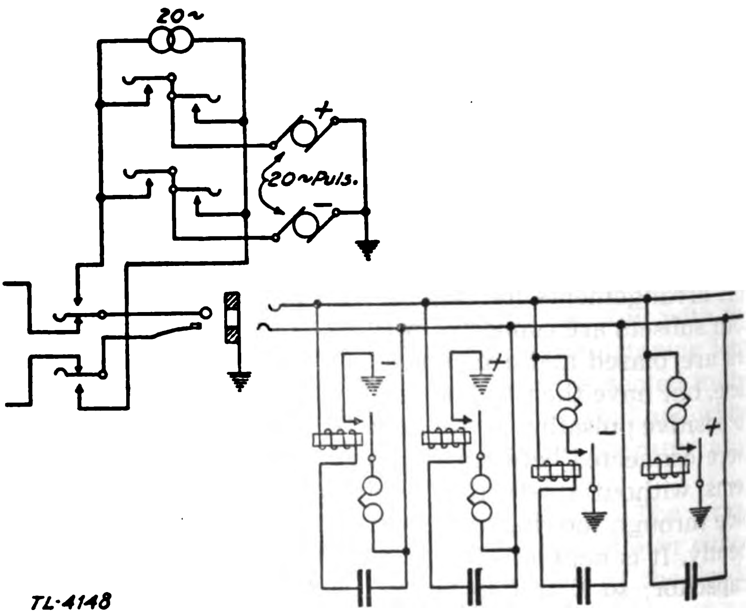

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FIGURE 57.—Four-party ringing with relays.

master key and four plunger keys. These plunger keys are marked *W*, *R*, *J*, *M*, respectively, and when any one is depressed it locks and remain down until another is depressed. One button connects positive pulsating current to the tip contact of the master key; another negative pulsating current to the tip contact; another positive pulsating current to the ring contact; and the fourth, negative pulsating current to the ring contact. Alternating current is also connected across the tip and ring contacts of the master key. To call any party the operator presses the proper key which connects pulsating current of proper polarity to the proper side of the master key. The master key is then operated and this places alternating current through all of the relays causing the four to operate and make their respective contacts, but since pulsating current was applied to only one side of the line and that of only one polarity, only the one ringer will operate, the other three remaining silent. The grounding of the ring side of the line during ringing is not objection-

able because the cut-off relay has removed battery from the line and the master key has removed battery from the calling cord. When ringing on a single-party line the alternating current operates the ringer instead of the relay.

b. Gas tubes—Four-party selective ringing.—A more recent development in four-party selective ringing employs a cold cathode, gas filled tube which replaces the relay and also eliminates the condenser in the ringing circuit of the subset. The tube is interchangeable with the relay and no change is necessary on the cord circuit at the central office. The 20-cycle a-c voltage applied to the line to operate the relay, however, is not required in this system. The tube contains three elements, a control anode, cathode and an anode, and its characteristics are such that a potential of 75 volts applied across the cathode and control anode will ionize the gas so that the tube will conduct current. The tube is also a rectifier since no current will flow between the anode and cathode except when the anode is made positive with respect to the cathode. Figure 58 shows a four-party line employing gas tubes in the ringing circuits. The tubes perform the same function as the relay in figure 57. When the gas in the tube is ionized, the ringer circuit is completed through the tube. The 150,000-ohm resistor in series with the control anode limits the current flowing between control anode and cathode. Pulsating voltage applied across either tip or ring and ground will ionize the gas of the tubes connected to that side of the line, and current will flow through the ringer circuit where the anode of the tube is made positive with respect to the cathode. Whether the anode or cathode of the tube is connected to the line or ground is determined by the bias of the ringers. One of the ringers on the tip side of the line will respond to negative and the other to positive current. Those on the ring side are also biased oppositely. The advantage in using the gas tube is that the tube requires no maintenance, has a long life, occupies less space in the subset, and is less expensive.

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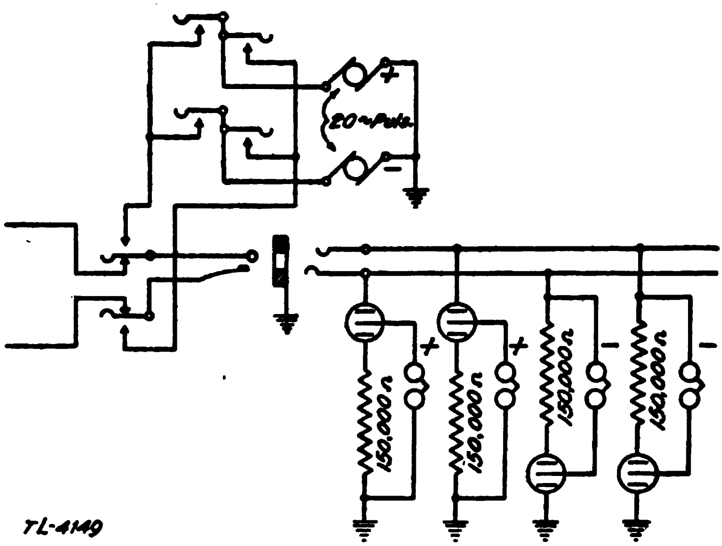

FIGURE 58.—Four-party ringing using gas tubes.

74. Harmonic ringing.—There is another four-party selective ringing system called harmonic ringing. The ringers of the subsets are connected across the line but these ringers are of a somewhat different design than that shown in figure 55. The armature, instead of being pivoted, can be moved only because of the spring in the clapper rod. This rod is mounted as a reed and each of the clappers for a given line has a different weight. The weight of each clapper is such that the frequency of vibration of the rod is that of one of the frequencies of alternating current generated, and the selection of frequencies for ringing is controlled by a key similar in design to that used in the four-party pulsating system. Instead of connecting ringing current to one side of the line only with the other side grounded, the key in this instance connects the ringing current across both tip and ring contacts of the master key. The frequencies

are either 16.6, 33.3, 50, and 66.6 or are 30, 42, 54, and 66. All ringers receive ringing current each time the line is rung, but only that ringer which is tuned to the frequency connected to the line responds. Ringing machines and ringers with this system must be closely adjusted and maintenance is high.

75. Party lines in army systems.—In army practice party line service is usually only a temporary expedient, the necessity for which ceases when adequate plant facilities are available. By confining the party line service to unimportant and little used telephones, usually code ringing or ringing to ground will prove satisfactory.

76. Questions for self-examination.—

1. What is a party line?
2. What is meant by code ringing?
3. Give two disadvantages of code ringing.
4. Name two methods by which these disadvantages may be overcome.
5. What is a lock-out system?
6. Why are not lock-out systems in more common use?
7. What is meant by selective signaling?
8. Name three methods of accomplishing selective ringing.
9. Show by means of a diagram how you would connect two telephones to a line so as to obtain selective ringing using only alternating current.
10. Draw a diagram of the ringing key combination that will accomplish the above.
11. Draw a diagram of a polarized ringer, equip the ringer so that it will operate on pulsating current and show the direction of the current through the windings for proper operation.
12. Show by means of a diagram a schematic of the line and cord circuit arrangement for two-party selective ringing using pulsating current.
13. Why is it that you cannot ring through a capacitor with pulsating current?
14. Explain operation of four-party selective ringing employing relays in subset.
15. What are the advantages of the gas tube over the relay used in the subsets in four-party selection?
16. Explain operation of four-party selective ringing employing gas tubes in subsets.
17. What is harmonic ringing?
18. What is a serious disadvantage of harmonic ringing?

SECTION X
AUXILIARY CIRCUITS

77. Auxiliary circuits.—The circuits additional to those already described are called auxiliary or miscellaneous circuits. It will be noted that certain of these may be common to both small nonmultiple switchboards and larger multiple switchboards. Also these circuits are either in the nature of refinements in the case of nonmultiple boards or additions to multiple boards performing functions of a more complex nature.

The following is a list of the more general of these circuits:

Auxiliary circuit	*Generally used with*
Line-pilot circuit	Multiple or nonmultiple board
Supervisory-pilot circuit	" " " "
Night-alarm circuit	" " " "
Generator-switching circuit	" " " "
Battery-switching circuit	Nonmultiple board
Transfer circuit	Multiple or nonmultiple board
Conference circuit	" " " "
Order-wire circuit	Multiple board
Test-cord circuit	" "
Wire chief's order-wire circuit	" "
Fuse-alarm circuits	Multiple or nonmultiple board
Peg count	Multiple board
Position and master clock circuit	" "
Supervisor's circuit	" "
Monitoring circuit	" "
Busy-back circuit	" "
Trouble-tone circuit	" "
Howler-cord circuit	" "

78. Line-pilot circuit.—On a busy switchboard some of the line lamps are occasionally obscured by the cords to other lines. If one of these hidden lamps should come on, the operator might overlook it and thus delay service on the call. The line pilot lamp is arranged to light every time that any line lamp comes in and this prominently placed signal light informs the operator that some party desires to place a call. The circuit by which this is accomplished is known as the line-pilot circuit. Figure 59 shows one type of circuit, and examination of this circuit reveals the fact that the battery side of all line lamps is connected to battery through a line-pilot relay. This relay is energized all the time that any line lamp is lighted. The armature of this relay closes a circuit through the line-pilot lamp causing it to light.

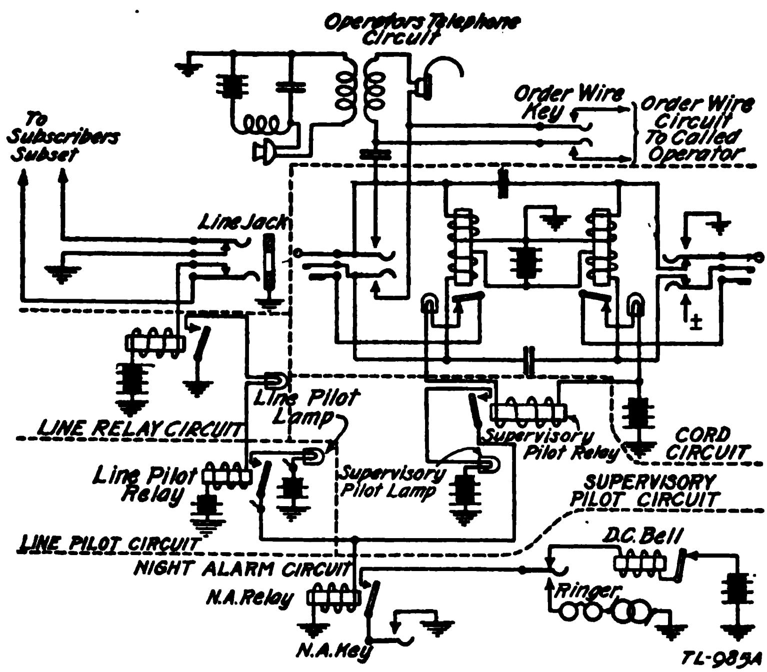

FIGURE 59.—Common-battery switchboard circuits.

79. Supervisory-pilot circuit.—When traffic through a switchboard is light, the operator is apt to overlook supervisory lights as they come in, and it is considered desirable to provide a pilot for those lights. Toll switchboards are generally arranged so that the pilot comes on when any supervisory signals come in, while in local

switchboards it lights only when an answering supervisory light comes on. Figure 59 shows retardation type of cord circuit equipped with a supervisory pilot that will light each time an answering supervisory lamp is lighted. This pilot circuit is connected to the night alarm circuit which is common to the board. Shunt type cord circuits are not arranged for supervisory pilot circuits, because of the fact that if several cord circuits were up in connection, sufficient current would be flowing to hold the pilot relay operated, thus giving a false pilot signal.

80. Night-alarm circuit.—The flow of current to each pilot light is over a common lead which goes to ground through the winding of the night-alarm relay. Thus, this relay will operate and remain operated as long as either pilot lamp is lighted. This closes a circuit which contains a key and a signaling device in series across a source of electromotive force. When the key is open no current will flow to operate the signaling device, but when the key is closed the signaling device will operate. This night-alarm key permits the operator to silence the night-alarm signal while he is at the switchboard, and to arrange for it to ring and call him to the switchboard during periods when traffic is light and does not require his full time at the switchboard. It will be noted that there is a selector switch in the night alarm circuit shown in figure 59 and that this switch permits the operator to cut either a ringer or a vibrating bell into the night-alarm circuit as the signal.

81. Generator-switching circuit.—The generator-switching circuit of a common-battery switchboard serves the same purpose as on a local-battery switchboard. A key allows the operator to transfer the normal ringing power source to an emergency source. This emergency source may be another power ringing supply or a hand generator. Figure 60 shows a typical arrangement of a generator-switching circuit.

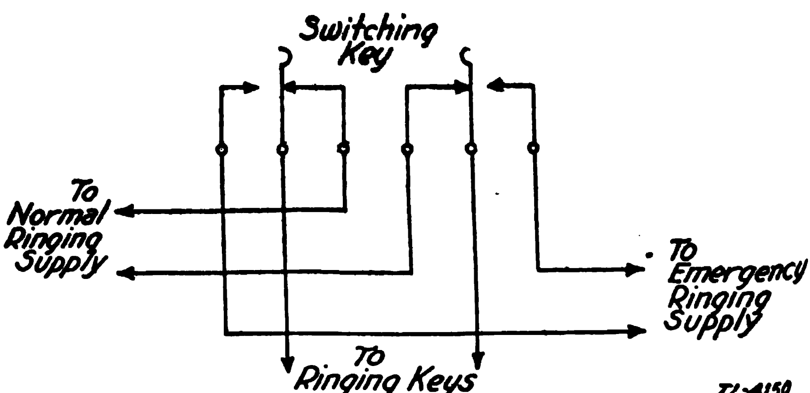

FIGURE 60.—Generator-switching circuit.

82. Battery-switching circuit.—Not all small switchboards are operated throughout the twenty-four hours of the day. Commercial PBX switchboards are usually equipped so that the operator can cut off battery and ground when taking the board out of service. The battery-switching circuit is not used on many army switchboards, unless they are installed as branch exchanges in office buildings or arsenals, etc.

83. Transfer circuit.—This circuit is for the interconnection of positions to enable several positions to be handled by one operator when the load is light. The circuit is similar to that used for the same purpose in local-battery switchboards. Throwing of the transfer key cuts the operator's telephone circuits together, enabling an operator on any one position to talk to subscribers over cords of the other positions.

84. Conference circuit.—If the type of service at a telephone central requires a circuit common to a calling party and two or more called parties, a switchboard with a conference circuit will be used. Figure 61 shows a typical conference circuit with five jacks. Such an arrangement would allow a conference between the calling party

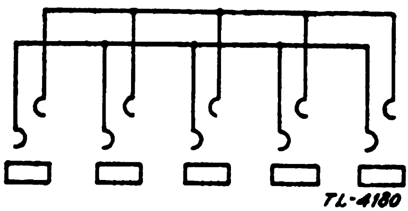

FIGURE 61.—Conference circuit.

and four called parties. All lines plugged into this circuit will be in parallel and therefore conversation is possible between all parties so connected. Army common-battery switchboards having conference circuits are BD-80 and BD-89.

85. Order-wire circuit.—An operator receiving a local call which must be trunked to another exchange for completing must make known to the operator at the other end of the trunk circuit the number desired by the calling party. If a separate means of talking between the two operators is to be provided, then auxiliary circuits are necessary. These circuits connect the telephone sets of

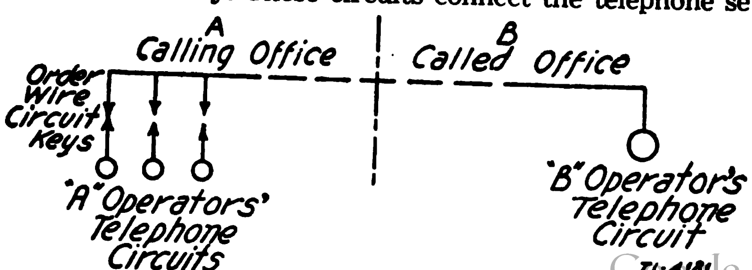

FIGURE 62.—Order-wire circuit.

the two operators together. Since one way trunking is more general, the order wire circuit is established by an order wire key at the switchboard of the calling office. Figure 62 is a schematic of a typical order wire circuit between exchanges *A* and *B*. It is to be noted that straight forward trunking, discussed in section XV, is superseding the order wire circuit for trunking operation. Similar order wire circuits may be used between operators of a multiple *A* switchboard, or between operators of an *A* board and a *B* board (see section XIV for usages of *A* and *B* boards).

86. Test-cord circuit.—A local exchange of any size will have a test board for testing local lines and line equipment.

It is necessary in this case that provision be made to connect any line appearing on the switchboard to the testboard for test purposes. The circuit for such connections is provided by one or more test cords at each of one or more positions on the switchboard. One end only of the test cord circuit appears in the form of a plug at the switchboard. The other end of this circuit terminates at the test board. Thus, at the direction of the person at the test board, any line circuit may be brought into the test board. It is now apparent that some means of communication between the test board and switchboard is needed. This need is filled by the wire chief's order-wire circuit which is taken up in the next paragraph.

87. Wire chief's order-wire circuit.—This circuit is similar to the one discussed in paragraph 85 as far as operation is concerned. The order wire key for completing the circuit is at the test board and there will be a key for each position which has test cords.

88. Fuse-alarm circuit.—When a fuse-alarm circuit is incorporated in a switchboard it is used to indicate a blown fuse on the battery supply line to cord circuits and other fused battery circuits. This alarm circuit is designed to close a common alarm circuit when any fuse blows. Thus the fact that a circuit has lost battery supply is indicated. Figure 63 shows a type of fuse-alarm circuit. Figure 73, paragraph 104, section XII shows the type of fuse used and the operation of the fuse in the alarm circuit.

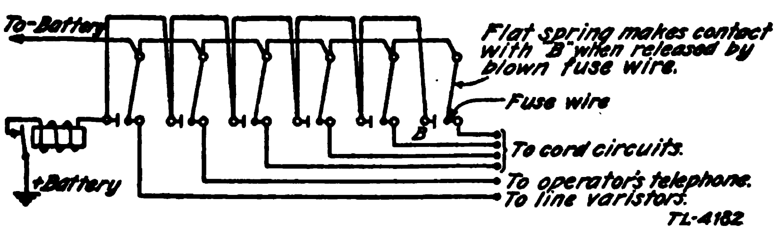

FIGURE 63.—Fuse-alarm circuit.

89. Other circuits.—The following list includes other auxiliary circuits which are beyond the scope of this text. (Brief mention is made of these in section XIV.)

Peg-count circuit
Position- and master-clock circuit
Supervisor's circuit
Monitoring circuit
Busy-back circuit

90. Questions for self-examination.—

1. What is an auxiliary circuit?
2. Name five auxiliary circuits usually found on a nonmultiple switchboard.
3. What is a line-pilot circuit?
4. What is the purpose of the above circuit?
5. What is the purpose of the supervisory-pilot circuit?
6. Do all switchboards contain a supervisory-pilot circuit?
7. Why is it not practicable to have a supervisory-pilot circuit on a switchboard with the shunt-out type of supervision?
8. Draw a diagram of a line circuit including line-pilot circuit and night-alarm circuit. Make your line circuit of the cut-off jack type.
9. Draw a diagram of a simple generator-switching circuit.
10. What is a transfer circuit?
11. What is the purpose of the conference circuit?
12. What is one method used to provide communication between calling and called office operators when a trunking connection is to be made?
13. What is a test-cord circuit?
14. Why would a person at the local test board require a wire chief's order-wire circuit?

SECTION XI
DISTRIBUTING FRAMES

91. Purpose of distributing frames.—In addition to the switchboard, a central office is equipped with facilities for permanently terminating the incoming lines and distributing them to the various jacks. It is the purpose of this section to give a description of the distributing frames found in various size offices. It is important that the functions of these frames be thoroughly understood. The principal function is to provide means for terminating the outside lines and also the switchboard lines in a permanent and orderly manner, and at the same time provide facilities for changeably interconnecting these permanently terminated lines among themselves by means of jumpers or cross connecting wires. The MDF (main distributing frame) is a natural dividing point between the outside plant and inside plant or between the outside lines and the switchboard lines. Therefore the MDF is the logical location of the central office protectors, to be discussed in a later section, which guard the inside plant from all outside hazards. The fact that all outside lines and all inside lines are permanently terminated on the MDF in such manner as to be readily identified and easily accessible, without disturbing any of the permanent wiring, makes the main frame the most convenient point from which to conduct many of the tests that are required both on the outside and inside lines. Finally, the use of another type of distributing frame makes it possible to shift the load of different operators and to change subscriber's numbers. This may not seem very important in a small office with one nonmultiple board, but in a large exchange with a multiple board it is of utmost importance. In fact without the use of such frames the wiring in a large central office would be a hopeless tangle.

92. Distributing frames for small offices.—Distributing frames are divided into two classes; wall and floor frames. In most small offices the wall-type frame is used; however, this will vary with local conditions such as probability of expansion, type subscriber served,

etc. In small army exchanges that use the switchboard BD-80 or BD-89, floor type frames are used. For the very small commercial installations with 80 or less lines, the wall frame is built up of units each one of which will take care of 20 pairs. This is the simplest form of frame and consists of two terminal blocks. The pairs from the outside are fastened to contacts on one block and the pairs running to the board are fastened to the other block. The two blocks are then interconnected by wires called jumpers, which can be fastened to any desired set of terminal lugs on either end. These jumpers are run through rings in order to make a neat and orderly arrangement and to aid in tracing out circuits. All connections are made by soldering. In actual practice protective devices are mounted on either one or the other of these terminal blocks. By the use of such a simple frame a place is obtained for mounting protective devices and also a convenient place to open the circuits for testing purposes. Schematically the circuit through the frame is as shown in figure 64

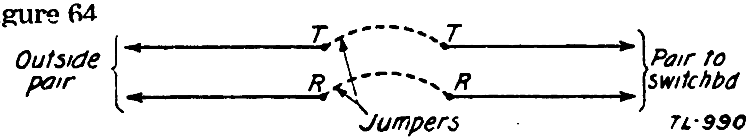

FIGURE 64.—Connections through a distributing frame.

93. Types of floor frames.—In general floor frames are of three classes:

(1) Those that have two vertical sides as the *FM-19* (TC-1) and BE-79 (TC-2). This type frame is used in small army exchanges.

(2) Those that have one side vertical and the other side a combination horizontal and vertical. This type is used in larger army exchanges and will be discussed later.

(3) The other type of floor frame is the standard frame that has one side vertical and the other horizontal. On all floor-type frames the two sets of terminal blocks are on opposite sides of the frame. Usually they are arranged in vertical rows on one side and horizontal rows on the other. These two sides are then referred to as the vertical and horizontal sides respectively. Figure 65 shows part of a typical distribution frame. The protectors are mounted on the vertical side. On the horizontal side are found the terminal blocks; each mounted in a horizontal position. When the vertical side is the switchboard side the frame is known as type *A* frame. With the horizontal side connected to the board, it is known as type *B* frame. The bridle rings are to assist in an orderly running of jumper wires between protectors and terminal blocks.

94. Distributing frames for large exchanges.—In large exchanges where all switchboards are of the multiple type, there is a great increase in the amount of central office wiring necessary. Thus a more elaborate system of distribution is required. To accomplish this it is common practice to use two distributing frames and, to distinguish between them, they are known as a main frame and intermediate frame. Each of these frames has a vertical and a horizontal side. The protectors are mounted on the vertical side of the main frame and it is to this side that the outside pairs are attached. Figure 66 shows the manner in which connections are made through the two frames.

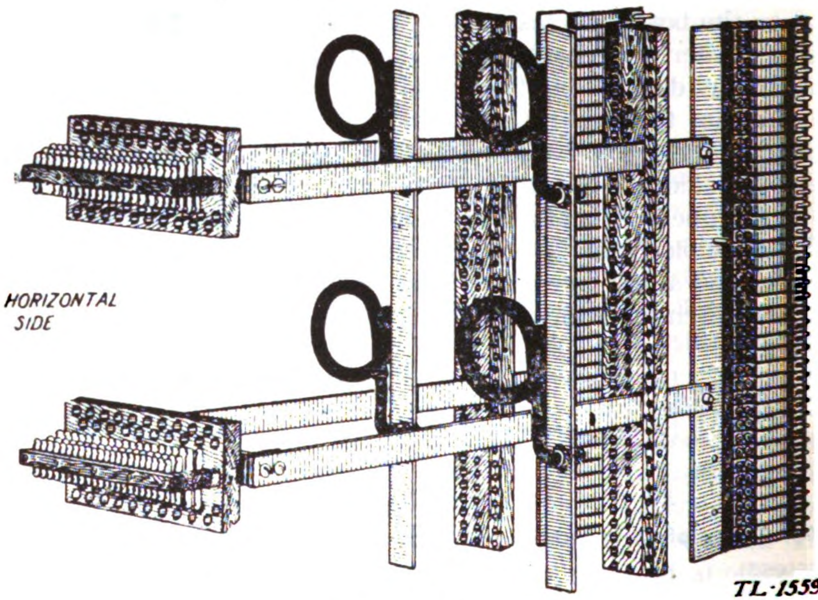

FIGURE 65.—Floor frames.

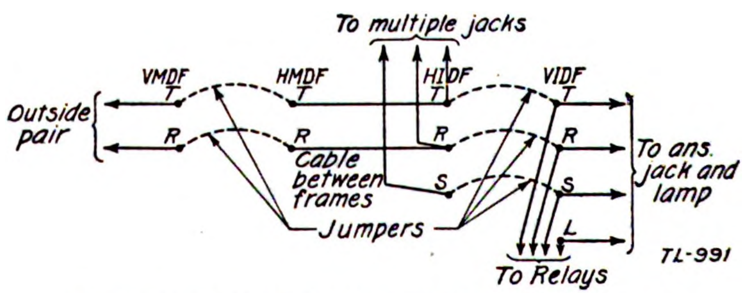

FIGURE 66.—Connections through standard MDF and IDF.

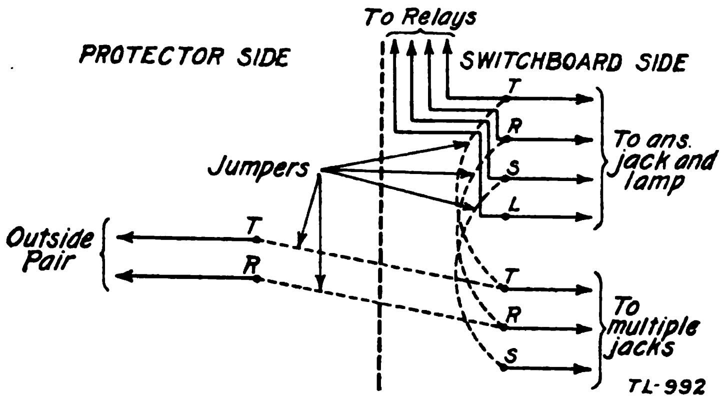

FIGURE 67.—Connections through combination MDF and IDF.

In the diagram, *VMDF* means vertical side of main distributing frame, etc. It will be noticed that two-wire jumpers are used on the main frame and three-wire jumpers on the intermediate frame. Since the telephone number is determined by the multiple jack to which the telephone is connected, the numbers of telphones are changed by shifting jumpers on the main frame. The load of the operators can be varied by shifting jumpers on the intermediate frame. The above means of distribution is used in all large commercial exchanges.

95. Distributing frames for larger army exchanges.—In some of the larger exchanges in the service which use multiple boards, a means of distribution is used which differs somewhat from the system described above. One frame known as a combined frame is used instead of the two. This method, of course, costs less but also some of the advantages of having the two frames are lost. The protectors are mounted on the vertical side of this frame as before and the outside pairs terminate on this side. The other side of this frame is a combination horizontal and vertical side, the lower half being horizontal and the upper half vertical. The lower half corresponds to the *HMDF* and *HIDF*, thus doing away with the cable that was used between frames and shown in figure 66. The upper half corresponds to the *VIDF*. Thus the two sets of jumpers are used on the one frame. Figure 67 shows a schematic diagram of this arrangement.

96. Switchboard cables.—From the distributing frame it is universal practice to conduct the lines to the switchboard in switch-

board cables. With 100-line and smaller boards, it is not uncommon to use a single cable to carry all the pairs. With some small boards and all larger ones, it is common practice to use as many 20-pair cables as may be required. These cables are usually a flat oval in cross section, so that they will pile evenly and maintain their place on the cable rack. The pile of cables is laced together and to the cable rack which supports it. This same type of 20-pair cable is used between the *HMDF* and *HIDF* in all large exchanges.

97. Cables from outside plant.—The cables of the outside plant are usually more easily introduced from below to the distributing frame. If the plant is underground construction, the entrance will be made from the cable vault, and if the plant is aerial, the entrance will usually be made through iron pipes which are brought down the office pole and come up beneath the distributing frame. In a small office with a wall frame aerial cables are often brought to the office by means of a cable rack extending from the building to the office pole.

98. Questions for self-examination.—

1. What is a distributing frame?
2. What is the purpose of using a distributing frame in a central office?
3. Describe the wall type of frame.
4. What type frame is used in a small office?
5. How is a jumper connected to the terminal contacts?
6. What type of main frame is used in a large exchange?
7. What is the difference between a type *A* main frame and a type *B*?
8. Upon which side of a main frame are the protectors mounted?
9. Under what conditions is it most practicable to use a separate main and intermediate frame?
10. When is it practicable to use a combined *MDF* and *IDF*?
11. How many conductors are there in an *MDF* jumper?
12. How many conductors are there in an *IDF* jumper?
13. Draw a diagram tracing a circuit through separate *MDF* and *IDF*. Show which leads go to the multiple, the jack, and the outside pair.
14. By what means is the *HMDF* connected to the *HIDF*?
15. How are outside cables usually brought in to the main frame?
16. Draw a diagram tracing a circuit through a combined *MDF* and *IDF*.

SECTION XII
CENTRAL OFFICE PROTECTION

99. Types of hazards.—*a. General.*—Telephone apparatus must be protected against electrical hazards which may be due to either natural or artificial causes. Lightning is the only noteworthy example of a natural hazard. Artificial hazards may be created from sources outside the telephone plant, such as excessive voltages or currents induced in the telephone wires from electrical systems and high power radio sending apparatus, being in close proximity to telephone lines; or from sources within the telephone plant, such as the accidental flow of current from the plant power supply in unexpected channels or in abnormal quantities.

Protective equipment must be provided to safeguard persons and property against all such hazards. All protective devices are designed so as to function properly before any damage to plant occurs, but they must not be be so sensitive as to cause unnecessary interruptions to service.

b. Classification of protective equipment.—Practically all outside telephone plant, except such conductors as are completely underground from terminal to terminal, may be exposed to one or more of these foreign hazards. Therefore whenever exposed wires are led into a central office or subscriber station, they are connected first through certain protective devices. The particular protective units employed and the manner in which they are connected into the telephone circuits vary somewhat with particular situations, but in general protective devices are classified as to the type hazard they are intended to guard against:

(1) Those forming a protection against small currents which become a hazard only when flow continues for an appreciable length of time. The heat coil is an example of this type.

(2) Those forming a protection against excessive currents. The fuse is an example of this type.

(3) Those forming a protection against excessive voltages. The air-gap arrestor is an example of this type.

In large exchanges where incoming cable is all underground, it is the practice to omit protector blocks and heat coils and to replace them with dummy apparatus. The only function the protector mounting serves in this case is to provide means for opening the lines for test purposes.

100. Heat coils.—*a. Common type.*—A heat coil consists of a small coil of resistance wire wound around a metal collar to which one end of the wire is soldered. The collar in turn is fastened by a low melting point solder to the cord. The whole is contained in a fibre shell for mechanical protection and heat insulation.

Heat coils are designed to protect against low potential currents. They operate on a small amount of excess current supplied over a period of time. The accumulated heating effect of the small current passing through the winding finally melts the low melting point solder and allows the core and the collar of the device to move with respect to each other. A Western Electric heat coil is installed with one end of the core pressing against a spring and when the coil operates, the core presses this spring in until it makes contact with ground. Thus, a heat coil in operating does not open the circuit but grounds the line. The Western Electric heat coil has a resistance of about 3½ ohms and operate on ½ ampere in less than 3½ minutes. Figure 68 shows a diagram of that coil (with the shell cut away) and the springs between which it is mounted. The coil is mounted

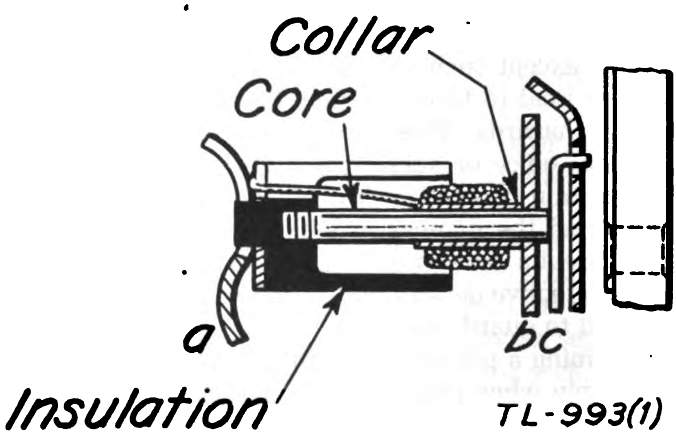

FIGURE 68.—Heat coil.

as shown between springs *a* and *b*, *b* is held rigidly while *a* exerts a pressure on the coil at all times in the direction of *b*. When the coil operates the pressure of *a* forces the core to move through the collar, pushing spring *c* against ground and thereby grounding the line. Thus, low potential current which might have gone through central office equipment and injured it has been provided with a direct path to ground.

b. Self-soldering type.—There is another type heat coil known as the "self-soldering" type. It derives this name from the fact that upon cooling after operation, it resolders itself so as to be again usable by a mere change of position in the protector mounting.

The most widely used coil of this type is shown in figure 69. The coil is provided with a ratchet on its outer edge, one of the teeth of which serves as a detent for the movable arrestor spring as long as the coil is prevented from rotating by the solder. When, however, the solder is melted, the ratchet is allowed to turn thus releasing the spring. These protectors are reset by merely placing the controlling spring in engagement with another tooth of the coil after

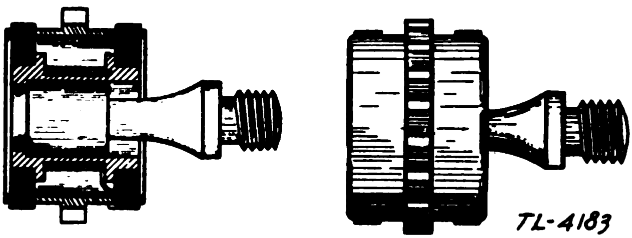

FIGURE 69.—Cook self-soldering heat coil.

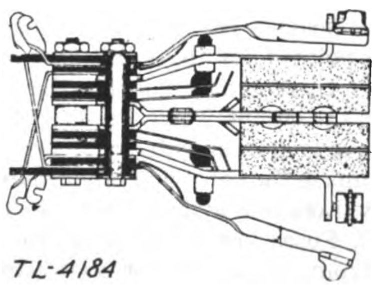

FIGURE 70.—Cook central-office protector.

the solder has again hardened. As shown in figure 70 the protector on top is in its normal position, the ratchet on the heat coil holding the long movable spring in its flexed position. When so held, the circuit from the outside to the inside line wire is completed through the heat coil. Also, by means of the insulating plunger engaged by

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the mid-portion of the movable spring, the two short inner springs are held out of engagement with the line spring.

The lower side of the protector in figure 70 is shown in the operated position. The solder has melted to the point where the ratchet has turned and released the long outer spring, thus opening the line circuit. Also by releasing the pressure on the insulating plunger, the two shorter springs are allowed to engage the spring forming the terminal of the outside line. The inner one of these short springs is seen to be in permanent connection with the ground plate and it thus serves to ground the outside line. The other one of the short springs also becomes grounded by engaging the now grounded line spring. It forms the terminal of an alarm circuit, which is thus energized to sound an alarm whenever any heat coil operates. This heat coil will operate in less than 210 seconds on 0.5 amperes and will carry 0.35 amperes for 3 hours with a room temperature of 68° F. As heat coils are used in conjunction with open space cut-outs in the central office, their location and the way in which they fit into the circuits will be shown later.

101. Fuses.—When a telephone conductor is grounded by operation of a protector, current will continue to flow through the telephone conductor to ground so long as the exposure continues. The current may be large enough to damage the telephone conductor or the protective apparatus itself. Accordingly it is necessary to insert in the conductor on the line side of the protector, a device which opens the conductor when the current is too large. Fuses are used for this purpose. Fuses designed for protection of telephone lines are tubular shells about 4 inches long inclosing a fusible wire of from 1 to 7 amperes capacity. Heat coils, of course, will function on the heavier currents resulting from high potential (class 3), but as pointed out above this does not open the circuit so that this heavier current may damage the cable unless a fuse is provided to open the circuit. The capacity of fuses is relatively high to prevent burn-outs on currents from low potentials which are insufficient to damage the cable and other material. In this case, the heat coil only will operate and prevent the current from reaching the switchboard. Fuses are provided at the central office for all wires entering from aerial cable or open wire but not for underground cable. In the latter case, it was formerly the practice to install fuses at the point where aerial plant went underground. Now it is common to use a section of smaller gage cable such as #24 or #26 at this point, which accommplishes the same result as if fuses were used.

102. Lighting arrestors or open space cut-outs.—Open space cut-outs are designed to protect against lighting or other extra high potential by affording a path for it to arc to ground. Figure 71 shows a

standard arrester in use today. The upper block is of porcelain. Imbedded in it and held in place by glass cement is a small rectangular block of carbon. The lower block is a solid piece of carbon. When mounted in the protector as shown in figure 71 there is a small air gap between the two carbon blocks. The right hand drawing of figure 71 gives a cross section through the two blocks and clearly shows this air gap. This gap forms the protection against high potentials existing between a line and ground. A lightning discharge across the gap will not usually cause a permanent grounding of the line, but, if a high potential exists long enough to maintain an arc for an appreciable length of time, the heat created will cause the glass cement to melt and allow the protector spring to force the smaller carbon block against the larger one. This will create a permanent ground.

The air gap space between the blocks is designed so that the operating voltage of the protector will be less than the break down voltage of the weakest point of the circuit which it is designed to protect and greater than the maximum working voltage of the circuit. The average operating voltage of the open-space cut-outs used at subscriber's stations and in central offices is about 350 volts.

The older type of lighting arrestor consisted of two rectangular carbon blocks separated by one thickness of U-shaped mica. The inner face of the grounded block has a fusible metal slug imbedded in it. An arcing current melts this slug and causes it to form a permanent path to ground. When mounted, the gap in the mica should be downward to prevent dust collecting in the gap between the carbons.

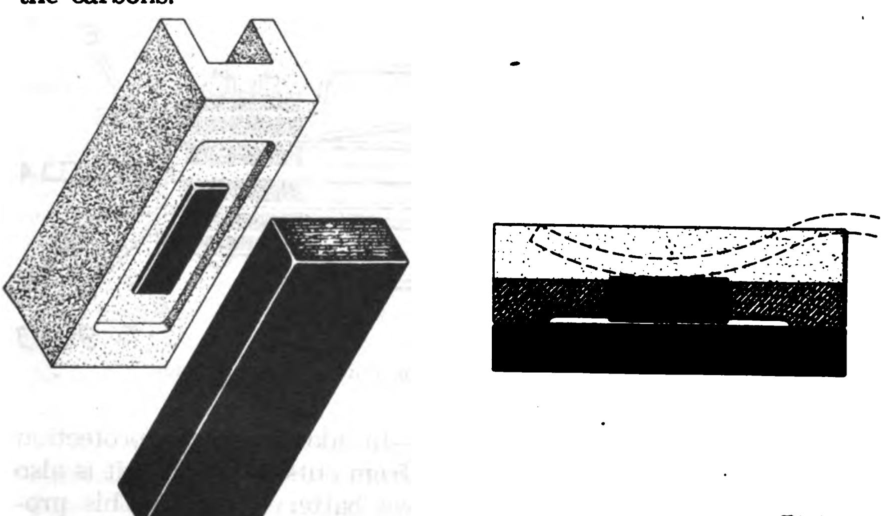

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FIGURE 71.—Open space cut-out

103. Protectors.—Lightning arrestors and heat coils are used together in a central office and the two combined are ordinarily called a protector. This protector is ordinarily referred to as a high potential sneak current protector. This is the protective device that was mentioned in the section on distributing frames. These protectors are in strips of 20 and are mounted on the vertical side of the main frame. As will be remembered there are two types of frames, *A* and *B*. The protectors for these two types differ slightly in their construction only. Figure 72 shows a *B* frame protector. *A* is a heavy metal center piece by means of which the protector is connected to the distributing frame and thus to ground. The outside pair (which is connected to the protector in a type *B* frame), is connected to *B* and *E*. The jumpers connect to *C* and *D* which are bought out on the same side of the center piece. The jumper is never split. This is always true whether the frame is of the *A* or *B* type. It should be noted that when the protector is used in line circuits, as in the case of conductors entering a central office, the heat coil is mounted on the office side of the open-space cut-out. In this position the heat coil wiring aids the operation of the open-space cut-out by presenting a considerable impedance to suddenly applied voltages such as are produced by lightning discharges.

The only difference between the *A* frame protector and figure 72 is in the arrangement of the spring assembly. The switchboard pairs connect to the protector in this case and are split, but the jumper is not. At the same time, the heat coils must be on the unexposed side of the arrestors.

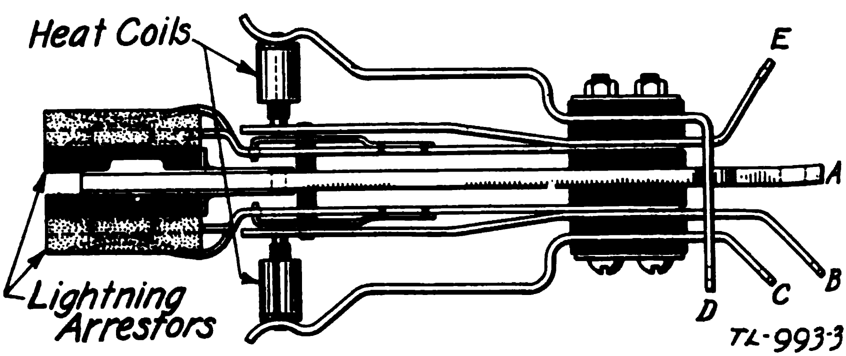

FIGURE 72.—Western Electric Co. central-office protector.

104. Switchboard fuses.—*a. Types.*—In addition to the protection afforded the switchboard apparatus from outside hazards, it is also protected from damage from its own battery current, This protection is provided by small fuses in each group of circuits. In a

large central office there are hundreds of these fuses. For continuity of service it is necesary for the office maintenance force to know the instant a fuse blows and to be able to locate it quickly. For this reason, indicating fuses as shown in figure 73 are used. As shown, the fuse is mounted outside between the battery bus and the stud on which the circuit (or group of circuits) fused by it terminates; and between these mountings is a thin bus bar which connects to ground through a pilot light and alarm bell. When any fuse blows both springs are released. The coil spring throws the glass bead out of line so that it can easily be seen and the flat spring makes contact with the fuse alarm bus, putting battery on that circuit. The ringing of the bell calls the attention of the attendant

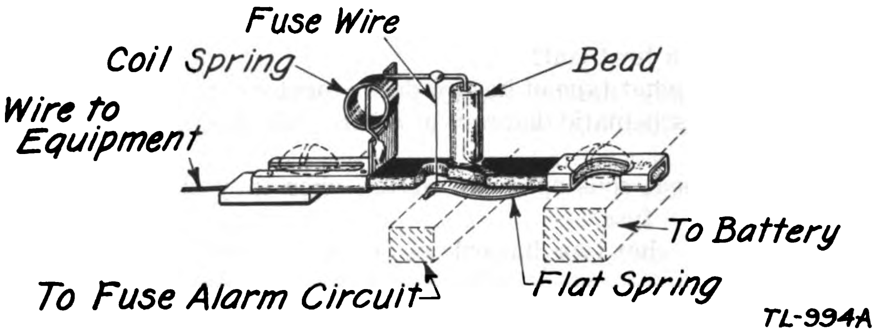

FIGURE 73.—Western Electric Co. 35-type alarm fuse.

and the particular pilot lamp burning shows him on which panel the blown fuse is located. By inspection of the panel for a fuse with the bead raised out of line the particular fuse is easily located. It is usual to replace one fuse without investigating the cause of failure, but if the second fuse goes out the cause of the trouble is searched out and cleared.

b. Fuse sizes.—Switchboard fuses are available in various sizes of which ½, 1⅓, 2, and 3 ampere capacities are most common. The fuse circuit prints will show which size to install in each case, and when replacing fuses the capacity of the fuse removed will show the size to use for replacement. To aid in the identification of the fuses and particularly to prevent a fuse of the wrong rating being used in a given place, the glass beads are variously colored. If the proper size of fuse is not available, use a piece of fuse wire of proper size. Never use a copper wire in place of a fuse, and never replace a fuse with another of larger capacity.

105. Acoustic shock reducer.—There is another piece of protective equipment found in the switchboard. This is a varistor-type acoustic shock reducer that is used in the operators circuit. In use, the varistor is bridged on the receiver branch of the operator's tele-

phone set, usually being wired across the receiver leads to the telephone jacks in the switchboard.

When the varistor has applied to it the relatively low voltages due to speech at ordinary levels its impedance is high (about 30,000 ohms at 0.1 volt) and it shunts from the receiver only a small amount of current. When relatively high voltages are impressed on the operator's telephone circuit the impedance of the varistor drops to a low value (about 15 ohms at 1.5 volts) and causes most of the current to be shunted from the receiver, thereby greatly reducing the intensity of acoustic disturbances.

106. Questions for self-examination.—

1. What is meant by a hazard?
2. Name three types of hazards to which telephone plant is exposed.
3. What is a heat coil?
4. Against what type of hazard does a heat coil protect?
5. Draw a schematic diagram of a heat coil, showing the circuit through it.
6. Do all heat coils open the circuit when they operate?
7. What is a fuse?
8. Against what type hazard does a fuse protect?
9. Why is it necessary to have both fuses and heat coils in the same circuit?
10. Is underground cable fused as it is brought in to the central office? Why?
11. What is an open-space cut-out?
12. Against what type hazard does an open-space cut-out protect?
13. What type open-space cut-out is used considerably in army exchanges?
14. Describe the older type cut-out containing the two carbon blocks.
15. What two protective devices are combined and called central office "protector"?
16. Where is this protector mounted?
17. Upon which side of the open-space cut-out should the heat coil be in this protector? Why?
18. Are the protectors used on *A*- and *B*-type frames identical? Why?
19. What type of fuse is used to protect central office equipment from the central office battery?
20. Why is this type of fuse used?
21. What is the purpose of the acoustic shock reducer?
22. Describe the operation of this acoustic shock reducer?

SECTION XIII
POWER EQUIPMENT

107. Central office battery.—The direct current source in a telephone office is usually a battery of the regular lead-acid type. In most instances the voltage of one of these batteries is 24 volts, however, certain types of equipment require 36 or 48 volts. The capacity of the battery depends upon the normal load of each individual installation. Care and maintenance of telephone central office batteries is in general the same as for any other battery of the same type and detailed instructions may be found in TM 11-430, Storage Batteries for Signal Communication.

108. Charging equipment—general.—As telephone central office batteries are in use almost continuously it is necessary to charge them while they are in use. This necessitates a uniform and ripple-free charging source, of adequate capacity to provide the charging current plus the normal exchange current load. There are many different types of charging equipment, to be used according to local conditions.

109. Motor-generator sets.—When an electric motor drives an electric generator, the combination is referred to as a motor-generator set. A set of this type is probably the most efficient charging equipment to use, where the charging rate is greater than fifty amperes. If the motor and generator of such a set are combined in one housing with a single rotor and the input and the output paths are conductively separate, they are known as dynamotors, however, when the input is alternating current and the output is direct current and the windings are conductively identical the machine is a rotary converter. When these sets are to be used as charging equipment, the generators should be designed to insure a minimum of commutator ripple.

110. Rectifiers—general.—A rectifier is commonly defined as a device for converting alternating current to direct current. Motor-generator sets first convert electric energy to mechanical energy, then to the desired type of electrical energy, and are not called rectifiers. Accordingly a rectifier may be somewhat more precisely defined as a device for converting a-c energy to d-c energy directly, or without an intervening step. All rectifying devices depend for their operation upon the characteristic of permitting electric current to flow through them freely in only one direction. They include a variety of vacuum and gas-filled tubes such as the older mercury-arc tube and the newer mercury-vapor tube, and the Tungar tube. In addition there are the dissimilar metal rectifiers, as the copper-oxide, and the selenium types.

111. Gas tube rectifiers.—Tubes of this type are commonly used as rectifiers when a power output of less than fifty amperes is desired. In this respect they function as "converters" of alternating current to direct current power. Very efficient rectifiers may be secured by admitting a small amount of certain gases at controlled pressure into the vacuum of a tube. In this case flow of electrons between the cathode and plate ionizes the gas by the electrons colliding with the gas molecules. The collision between an electron and a gas molecule knocks some electrons out of the molecules, thereby separating it into a positive ion and one or more electrons. The electrons, being negative, are attracted to the positive plate, and the ions being positive travel to the cathode. The positive ions neutralize the negative space charge that would otherwise exist near the cathode, thus greatly facilitating the escape of additional electrons. The net result is that the opposition to the space current flow is reduced, which permits the current to increase to a value limited primarily by the external resistance in the plate circuit. Mercury vapor and argon are the two gases most commonly used in these tubes.

112. Half-wave rectification.—Figure 74 illustrates schematically a general type circuit, as used in half-wave rectification, for a two-electrode gas tube. In the particular tube illustrated, the cathode is of the filament type and is heated by a low voltage current. In

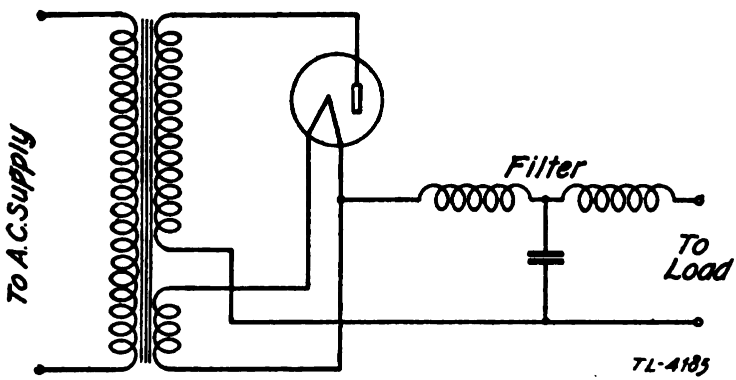

FIGURE 74.—Half-wave rectifier.

figure 74 the alternating voltage in the secondary side of the transformer is impressed across the plate and cathode of the tube. The flow of space current, of course, occurs only during the time the plate is positive with respect to the cathode. This means that during the positive half-cycle there is a current flow between the cathode and plate which gives the effect of closing the circuit or connecting the filter and load to the transformer. During the negative half-cycle (plate negative with respect to the cathode) there is no space current and the tube may be considered as opening the circuit. The output current from the half-wave rectifier flows in one direction, but its magnitude varies as the positive half of the impressed wave and is therefore of a pulsating character. By adding a filter in the output containing series inductance and shunt capacitance, this pulsating current is smoothed out into a more even direct current.

113. Full-wave rectification.—Many commercial companies manufacture full-wave rectifiers of the type shown in figure 75. There are of course slight modifications by each manufacturer, of which the tube is the most outstanding. In figure 75 the tube has two separate plates, to which are connected the terminals of the trans-

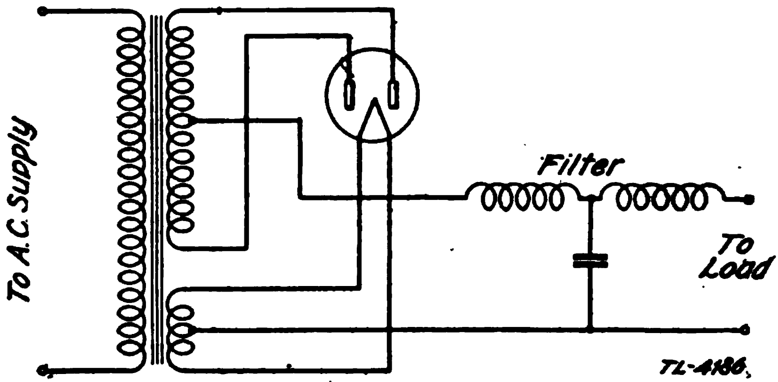

FIGURE 75.—Full-wave rectifier.

former secondary winding. It can be seen that when a voltage is impressed on the primary one of the plates will always be positive with respect to the cathode. This means there will be current flowing in the same direction in the output (filter and load) during both positive and negative half cycles, or the rectifier is said to be full-wave. As the full-wave rectifier uses both halves of the cycle, its power output is approximately twice that of the half-wave rectifier, and the filtering requirements are less severe, i.e., done more easily.

114. "Tungar" tube rectifiers.—Of all the various gas-filled tubes used for rectification the "Tungar" is probably the best known and most widely used in the army. This tube is manufactured by many different firms, and consists of a single carbon plate and an ordinary tungsten filament within a gas filled (usually argon) tube. Operation is basically the same as for any tube rectifier; however, as there is but one anode in each tube, two tubes must be utilized for full-wave rectification. Figure 76 is a schematic diagram of one way in which these tubes may be connected for full-wave operation.

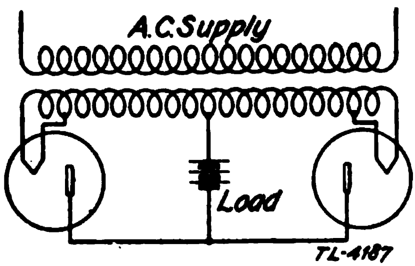

FIGURE 76.—Full-wave "Tungar" rectifier.

115. Mercury-arc rectifier.—The mercury-arc rectifier is a pear-shaped glass bulb, evacuated of air and having in the bottom a little mercury. Into the glass bulb penetrate four iron terminals, iron being used because mercury does not amalgamate with it. In figure 77 three of the terminals are *C*, *D*, and *F*; the fourth is just beneath the pool of mercury at *E*. In the figure is shown connected the alternator whose current is to be rectified; the battery between *E* and *J* is to be charged by the rectified current. The inductances *G* and *H* are auxiliary apparatus necessary to the functioning of the rectifier.

a. Mercury vaporizes very little at ordinary temperatures and pressure, hence the gas pressure within the bulb is low, and once the gas is ionized it will conduct very well. To start the rectifier, the bulb is tipped to the left allowing the mercury to short circuit terminals *E* and *F*. This would be a short circuit upon the alternator were it not for the resistance, *R*, connected in to limit the current to a reasonable value. When the bulb is righted, the mercury runs back to *E*, breaking the circuit. But the inductance of the circuit causes an arc to form at the break of the mercury stream and some of the mercury is ionized by the arc. Let us suppose that

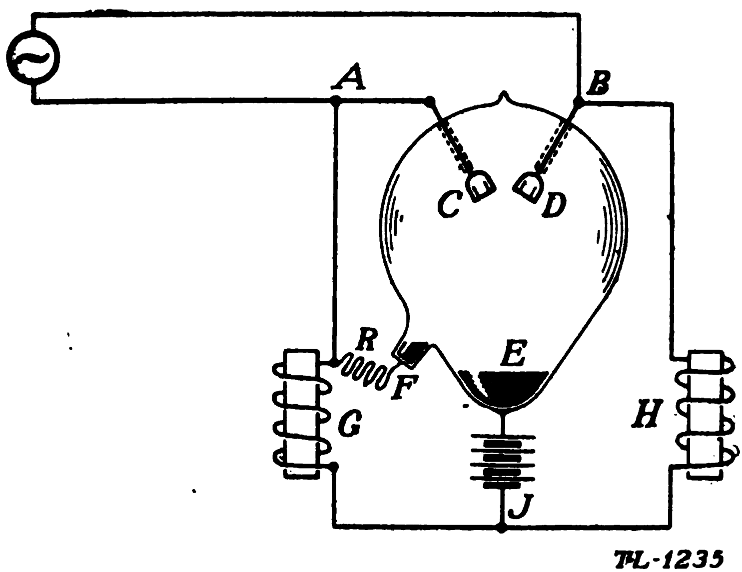

FIGURE 77.—Mercury-arc rectifier.

at this instant the emf of the alternator is acting from the alternator towards *A*. Then *C* is at a higher potential than *E* which is connected to the other terminal of the alternator. The positive ions will be attracted to *E* and the electrons to *C*; there is a current flow from the alternator through the path *ACEJHB*. This current is conducted within the bulb by the stream of ions and electrons.

b. The emf of the alternator dies down preparatory to reversing its direction, but the current does not begin its decrease as soon as the emf because the inductance *H* causes the current to lag behind the emf. When the current does decrease, *H* opposes this decrease by an induced emf acting in the direction of current flow. This induced emf acts from *J* to *B*, making *D* of a higher potential than *E*. Thus, before the alternator has made *D* positive with respect to *E*, current has begun to flow from *D* to *E* because of the discharge of *H*'s energy. The induced emf acting from *J* to *D* outside the bulb, because of the inductance *H*, lasts only an instant but it is long enough for the alternator to have built up towards *B* a sufficient voltage to maintain the current flow through the bulb. When the emf of the alternator again reverses direction, *G* plays the same part as that just played by *H* in maintaining the current flow and ionization within the bulb until the alternator has begun to build up in the new direction. In the part of the circuit *E* to *J*, it is seen that the direction of current flow is always the same. Hence, a battery placed there may be charged, or there may be connected between *E* and *J* any load requiring direct current. As the output of the rectifier is pulsating a filter must be added between *E* and *J* to smooth out the output for use in a telephone central office.

116. Copper-oxide rectifiers.—There is a rectifier that has no moving parts and does not use a gas-filled tube. It operates on the principle that if two dissimilar metals are in contact, current can flow more easily in one direction than in the other. Notable in this category are the selenium rectifier and the copper-oxide rectifier. As the only difference in these units is the metal used in the individual rectifying element, a discussion of the copper-oxide rectifier will suffice for the elements made of other metals. Copper and copper-oxide are used in the same manner as two dissimilar metals, to form the element of the copper-oxide rectifier. This combination offers low resistance to current flowing from the copper-oxide to the copper, but offers a comparatively high resistance to the flow of current from the copper to the copper-oxide. Thus it becomes of value for the rectification of alternating currents.

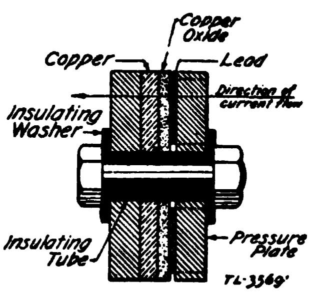

FIGURE 78.—Rectifying element arrangement.

a. Assembly.—Good electrical contact to the oxide is secured by pressing it into a lead washer. Several elements as shown in figure 78 can be placed together in a series or parallel arrangement to build rectifiers of the desired capacity or characteristic. The assembling is held together by means of heavy pressure plates secured by bolts. For best operation, the pressure should be between 500 and 2000 pounds per square inch. Figure 79 shows a copper-oxide rectifier unit.

b. Aging.—The resistance of a copper-oxide rectifier increases during the first two to three months it is in use. This is known as "aging" and will cause the resistance to increase about 25%. Heating both hastens and increases the effect of this aging. Units should not be run with an overload. Various methods have been devised to overcome the effect of aging and two of the most common means are: plating the lead washer with tin, and coating the oxide with graphite.

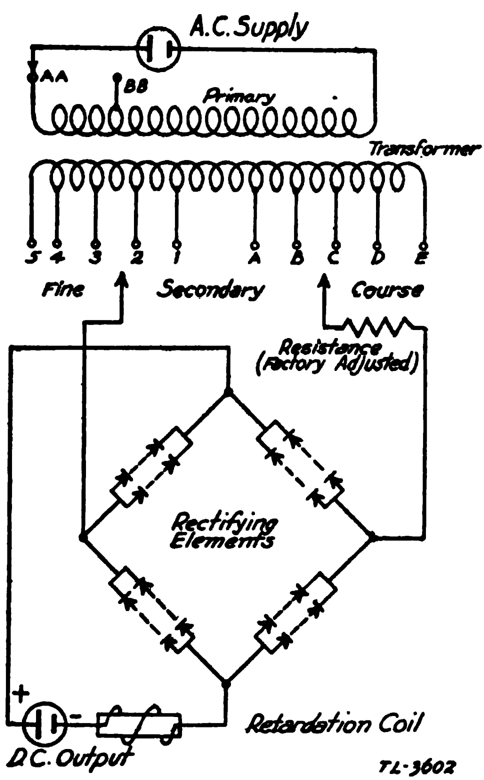

FIGURE 79.—Copper-oxide rectifier.

c. Adjustments.—Ordinarily there is a transformer in the input which is provided with taps in order to regulate it to the required potential. Resistances are provided in some cases to compensate for

variations in the rectifier output due to manufacturing variations or variations in line regulation. On copper-oxide rectifiers, that are used to charge storage batteries used in telephone systems, a retardation or choke coil is provided to smooth out the rectified current. This coil must always be provided in order to prevent noise in the voice frequency range from entering the battery.

117. Ringing machines—general.—Many different frequencies are used for ringing in telephone work, 16⅔, 20, 33⅓, 50, 66⅔, 1000 cycles etc.; however, most of these are for special cases, i.e. harmonic ringing, carrier use, etc. Of all these frequencies 20 cycles is used most frequently. As in the case of charging equipment a motor-generator may be used as the power source, in which case it provides a number of things, i.e., busy signal, dial tone in automatic exchanges, etc. Motor magnetos are also in use, although mostly in old installations, and are being replaced with newer equipment. Many manufacturers make very compact and efficient ringing machines to fill the need of the small central office in a more efficient manner than is possible with the above equipment. The following ringing machines of this type have been generally adopted as standard:

a. The "Telering."

b. The "Sub-cycle" static frequency converter.

c. The vibrating pole changer.

The output of each machine is isolated from battery and power circuits, allowing the ringing current supply to be connected to battery or used to ring directly to ground at the telephone exchange equipment.

118. The "Telering."—This instrument was devised to produce a 20-cycle ringing current from a 110-volt 60-cycle power input. It is included as part of the Telephone Central Office Sets TC-1, TC-2, and TC-4. The principal of operation of the Telering is the utilization of two frequencies to produce a beat frequency. This beat frequency is the difference between the 60-cycle input and the resonant frequency of a vibrating reed. Figure 80 is a schematic diagram of the model "H" Telering. Fundamentally, it has the same circuit as other models. Referring to figure 80, let us assume that the instant the circuit is closed, current is flowing in at *L-1*, through the fuse and the primary of the transformer and through the other fuse to *L-2*. A voltage is induced in the secondary of the transformer in the direction of the arrow to point *A*. Here it divides, part flowing through the fifty-watt lamp and the output load, and part through the 2000-ohm resistor and the winding of the motor coil. The current flows through these two circuits and

joins at the vibrating reed. From the vibrating reed it flows through the *R.F.* choke and back to the secondary of the transformer. As long as the circuit is closed between the vibrating reed and its contact, current will flow through the output load. This first half-cycle, or alternation, through the motor coil, causes the reed to sweep toward the motor coil, opening the circuit. The circuit being opened,

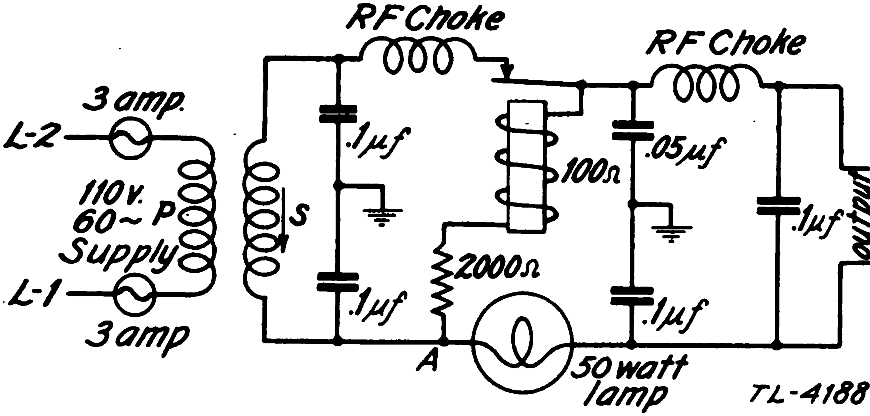

FIGURE 80.—Model "H" Telering.

the motor coil de-energizes and the reed sweeps back and closes its contact. In this manner, the reed is kept vibrating continuously. The contact at the reed, being common to both the motor coil and the output, allows an impulse to go through the fifty-watt lamp to the output each time the contact is closed. Due to the characteristics

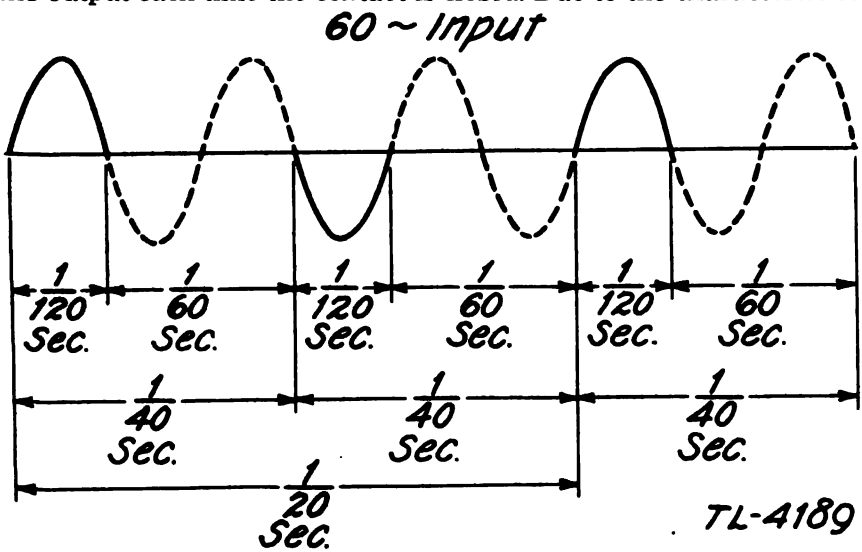

FIGURE 81.—20-cycle output of the "Telering."

of the tuned vibrating reed, the contact is closed for $\frac{1}{120}$ of a second and open for $\frac{1}{60}$ of a second. The input is 60 cycles, or 120 alternations per second; therefore, each alternation takes $\frac{1}{120}$ of a second. When the contact at the reed is closed for $\frac{1}{120}$ of a second, one alternation is permitted to flow through the output. The contact is then opened for $\frac{1}{60}$ of a second and two alternations of the input are missed and not allowed to flow through the output. It can be seen from figure 81 that 40 alternations or 20 cycles are selected per second, and allowed to flow into the output.

119. The "Sub-cycle" static frequency converter.—This apparatus is a frequency reducing device which furnishes ringing power at a sub-multiple of the power supply frequency. The Sub-cycle does not use any moving parts while operating. They are available for operation on 115-volt 60-cycle and for 115-volt 50-cycle power. For other commercial voltages at these same frequencies, a transformer is inserted between the converter proper and the power supply line, so as to bring the input voltage within the rating of the device, as given on the name plate. The output frequency of the Sub-cycle is one-third of the input frequency. The maximum output is 20 watts which is sufficient to operate 25 ringers simultaneously with average line conditions. The output voltage at no load is 90 volts across the secondary winding. From no load to full load, the output voltage drops no more than eight volts.

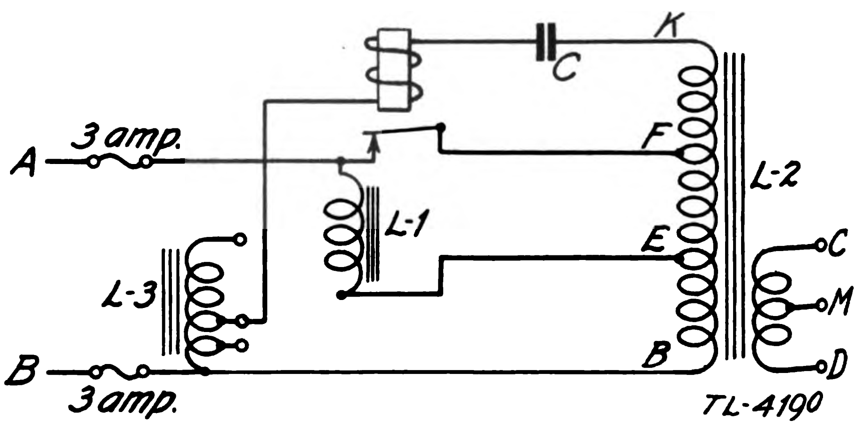

FIGURE 82.—"Sub-cycle" static frequency converter.

a. Starting.—The 115-volt 60-cycle supply is applied to points *A* and *B*, figure 82, through the three-ampere fuses. With the relay at normal, the input supply is connected to the winding *FB* of transformer *L–2*. The transformer operates as a 60-cycle auto-transformer at this time, stepping up the voltage to approximately 440

volts across its winding *KB*. This high voltage is applied to the 8 μf capacitor *C* through *L-3* and the relay winding. The resistances of *L-3* and the relay winding are approximately 2 ohms each and have a negligible effect on the charging current of the capacitor. A large charging current rushes into the capacitor, energizing the relay. The operating time of the relay is such that it operates about the time capacitor *C* has charged to the peak value of the 440 volts. The operation of the starting relay allows the charge stored on the capacitor to discharge through winding *KB* of transformer *L-2* causing a starting current to flow through series inductance *L-1*. Thus, the resonant circuit formed by inductance *L-3* and the capacitor *C* coupled by the transformer *L-2* is started oscillating at its resonant frequency of 20 cycles per second. In this particular case, choke coil *L-1* is a low resistance inductance which saturates sharply with voltages greater than 115 volts at 60 cycles.

b. Operation.—While the 20-cycle circuit is oscillating freely, there will be successive times when the potentials of the 60-cycle supply and the 20-cycle oscillations counteract current flow through *L-1* and other times when they do not. For the former condition *L-1* will have a high impedance, but for the latter condition *L-1* will saturate and have a low impedance. Thus, a large current flows from the 60-cycle source when in a direction to aid the flow of the 20-cycle current; but a very small current from the 60-cycle source flows at all other times due to the high impedance of *L-1* when not saturated.

c. Restarting.—In case of a momentary overload, the external load requires so much power that the circuit will be unable to maintain the 20-cycle oscillations. As soon as the oscillations through capacitor *C* and winding *KB* stop, the relay will release and automatically restart the converter. In case of a prolonged overload, the capacitor *C* will be repeatedly charged by the automatic restart operations of the relay. The successive large charging currents will burn out the three-ampere fuses to protect the machine. The relay has no function in the normal operation of the converter, but plays an important part in automatically starting and restarting the machine. The Sub-cycle requires only 20 watts no-load power, which demonstrates its economy of operation, even where continuous operation is necessary. Stability of the converter is not affected by relatively wide variations in either the frequency or the voltage of the commercial a-c supply. A self-regulating characteristic maintains better voltage regulation of the output than any attempt at regulation of the input voltage.

120. The vibrating pole-changer.—This unit has been designed for use as a source of ringing power, where direct current is to be used for power. There are several different types of interrupters designed to fill the needs of various ringing requirements. The output may be either or both polarities of pulsating direct current, or alternating current, and the input may be one of several voltages, according to the individual central office. As the Western Electric type 84 interrupter is a component part of the TC–1 and TC–2, it will be used as an example. This interrupter, as used in the TC–1 and TC-2, operates on the regular central office storage battery, and puts out 20-cycle alternating current as ringing power.

a. Starting.—Figure 83 is a schematic representation of the circuit of the type 84–F interrupter, as used in the TC–2, while at rest. When the power is turned on current flows from the positive (grounded) side of the input through the break contact on the vibrator, through the motor coil, and returns to the negative side of the input and back to its source. As soon as the motor coil is energized, it attracts the vibrator and makes the contact at *B*. As the key is closed there is now a complete circuit from point *A* through *B* and the key and then through the lower half of the primary of the repeating coil, to ground and back to its source. During the time this current is flowing an emf is induced in the secondary of the repeating coil thereby allowing the first half cycle to flow to the output.

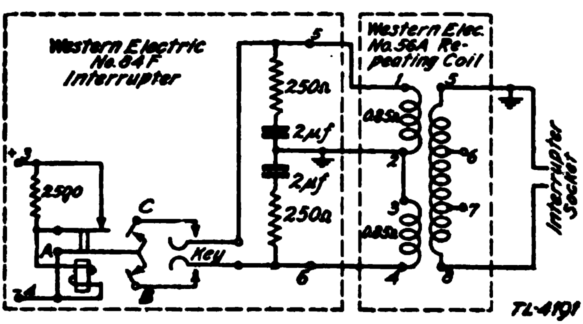

FIGURE 83.—Circuit diagram of the 84–F interrupter.

b. Operation.—As soon as the motor coil operates, the break contact on the vibrator is broken causing the circut to open and de-energize the motor coil. That allows the vibrator to swing back and close the vibrator contact and allows current to flow to point *A*, through *C* and the key and thence through the upper half of the primary of the repeating coil to ground and back to its source. An emf is now induced into the secondary in the opposite direction as fore, causing the second half-cycle to flow through the output.

It can be seen that the input direct current has been changed to alternating current at the output. The frequency is controlled by the vibrator, in this case to allow the output to be 20 cycles. The 2500-ohm resistance is across the vibrator contacts and prevents excessive sparking. The two 250-ohm resistors, and the 2μf capacitors that are across the primary of the repeating coil, act as a filter for the output.

121. Questions for self-examination.—

1. What type of storage battery is used in a central office?
2. What voltage is usually used?
3. What two general types of equipment are used for charging telephone batteries?
4. What is a rotary converter?
5. What is a dynamotor?
6. Define rectifier.
7. What is a full-wave rectifier? A half-wave rectifier?
8. What type of rectifier is generally used in the army for battery charging?
9. What type of gas is usually found in the tungar tube?
10. Explain the operation of the copper-oxide rectifier.
11. What is "aging" as applied to copper-oxide rectifiers?
12. What is the frequency of the ringing current most often used?
13. What types of ringing machines are generally found in small exchanges?
14. Explain the operation of the Telering machine.
15. Explain the operation of the Sub-cycle ringing converter.
16. Where and when is the vibrating pole-changer used?

SECTION XIV
NONMULTIPLE AND MULTIPLE SWITCHBOARDS

122. Nonmultiple army exchange switchboards.—The circuits described in the foregoing sections complete the requirements for a nonmultiple common-battery switchboard. The army uses many different types and sizes of these small switchboards which are manufactured for use as commercial branch exchanges but when installed in small army posts they are used as the main exchange switchboards. In some of the larger posts they are used as branch exchanges for hospitals or other centralized activities. These switchboards are housed in oak or mahogany cabinets similar in design to those used in local-battery switchboards. They are not so tall as local-battery boards because the substitution of lamps for drops has reduced the vertical space requirements. Common-battery switchboards are, however, slightly deeper than local-battery switchboards because some of the relays, condensers, and other circuit equipment are mounted in the back of the cabinet. Since the greatest part of the cost of any switchboard is the cost of the circuit equipment, it is the general practice to provide a cabinet of sufficient capacity to serve the ultimate requirements or the maximum load of a single operator. The switchboard is usually wired for the full capacity of the framework, but only those circuits which are actually required are equipped initially. It is possible thus for a switchboard to be wired for 100 lines, 15 trunks, and 15 cord circuits and equipped

for only 40 lines, 8 trunks, and 10 cord circuits. When the load increases beyond the capacity of the initial equipment of such a board, it is an easy matter to remove the apparatus blanks and install additional equipment. For details of the circuits employed in these switchboards refer to the sections covering line circuits, cord circuits, and trunk circuits.

123. Limitations of nonmultiple switchboards.—Two single-position switchboards may be placed side by side to handle traffic up to the operating capacity of two operators. An operator at one position will have no difficulty in reaching across the other position to establish a connection between two lines appearing on different positions. When traffic volume becomes too great to be handled by two operators, the addition of a third position does not always afford a satisfactory solution. The operator at the end positions cannot easily reach the jack field of the other end positions. The use of interposition trunks (trunks connecting two positions of the same switchboard) enables any operator to give connection to lines appearing on the distant positions. This is a practical scheme where there are not more than three or four positions in the exchange, but the slight increase of time in placing each trunk call is usually considered objectionable. When the exchange is of five or more positions the system of interposition trunks becomes quite complex, and the errors in trunking further lower the efficiency of the service rendered. The provision of a multiple-type switchboard is advisable, in most cases, when the estimated ultimate requirements are three or more positions.

124. The multiple switchboard idea.—The width of jack field over which an operator may comfortably reach is about six feet, and within such a width not more than three operators can comfortably work. When more than three operators are required the multiple switchboard meets this space problem by the simple expedient of placing a complete appearance of jacks (one for each line) within a unit jack field small enough so that all jacks are easily reached by one operator. This unit jack field is then repeated along the length of the board so that each operator has within easy reach a multiple jack for each subscriber line in the office. A sufficient number of positions is provided to accommodate the number of operators required to take care of the traffic during the busiest period at the desired level of efficiency. The jacks in these fields that are repeated at regular intervals along the boards are termed "multiple jacks" and the entire aggregation of them with their connecting wiring is referred to as the "multiple." Various types of multiple schemes are discussed in following paragraphs.

125. Branch multiple.—The common-battery line circuit using cut-off relays for signaling may be arranged as shown in figure 84 with several jacks, all having their tip, ring, and sleeve contacts connected in parallel. The signaling equipment will be disconnected by sleeve current if a cord circuit plug is inserted in any of the jacks. This arrangement is known as a branch multiple. It should be noted that the equipment of the line circuit is in five groups,

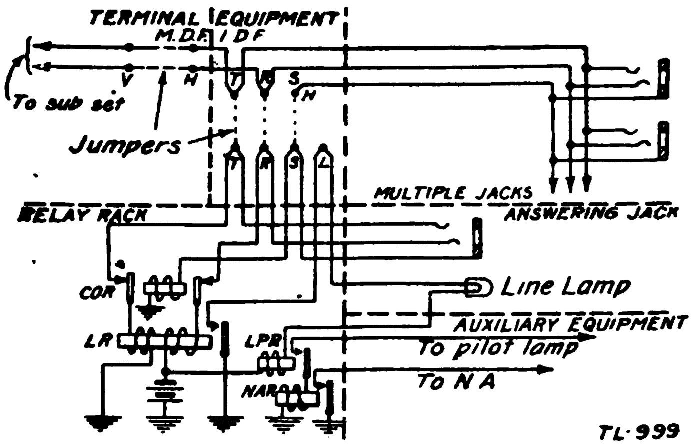

FIGURE 84.—Multiple circuit.

namely, terminal equipment, answering jack equipment, multiple equipment, relay equipment, and auxiliary equipment. The last mentioned is common to all lines appearing on a single position. The answering equipment consists of the line jack and associated line lamp and is fed from the terminal equipment. Likewise, the multiple equipment is fed from the terminal equipment. The relays too are connected to the terminal equipment. The advantages of this arrangement are simplicity, ability to segregate the relay equipment on a framework outside of the switchboard cabinet and obtain a higher order of flexibility.

126. Equalization of traffic load.—The calling number of any subscriber depends upon the number of the jack with which his line is associated in the multiple. It is possible to change the calling number of any line, by changing the jumper on the main distributing frame. Numbering in the multiple cannot be rearranged because the jacks must be placed in numerical sequence to enable any operator to locate quickly the jack of the line called. This however is not the case with answering jacks, since they are never used for outgoing calls on this type of commercial switchboard. Answering jacks on each position are numbered from "0" upward

The branch multiple system enables any answering jack and associated relay equipment to be connected to any multiple number by the changing of a three-wire jumper on the intermediate distributing frame. This makes it possible to shift the answering jack assignment of any line from one position to another, without changing the calling number, and facilitates the equalization of the traffic load on all positions without change of directory listings.

127. Lamp associated multiple.—There are multiple installations where each multiple jack has a line lamp associated with it as shown in figure 85. In this case there is no separate answering jack, and when any line calls, all lamps light simultaneously. The first available operator plugs into the multiple and answers the call, extinguishing all lamps. This arrangement effects an automatic distribution of load, but it reduces the capacity of the switchboard considerably, increases battery drain and is likely to result in two or more operators answering the same call. It is known as the lamp associated multiple system. It is coming into wide use in small commercial exchanges.

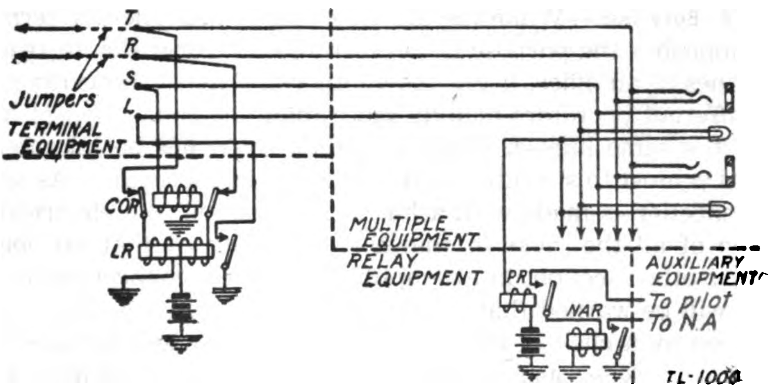

FIGURE 85.—Lamp associated multiple circuit.

128. Series multiple.—Another type of multiple jack arrangement as used in the Signal Corps switchboard BD-80-A is shown in figure 86. In this multiple arrangement the jacks are connected in series through cut-off springs and contacts in each jack. Since cut-off jacks are used instead of relays to operate the line lamps, this series arrangement of multiple jacks is necessary in order to extinguish the line lamp when a cord plug is inserted in a multiple appearance jack. On this switchboard the answering appearance is also used for outgoing calls since it is the only appearance of the line on that position of the board. The switchboard BD-80-A does not require an intermediate distribution frame. The multiple connections are made by a standard cable arrangement.

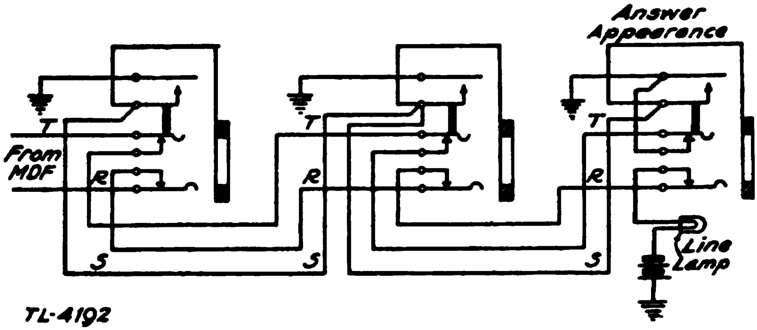

FIGURE 86.—Series multiple circuit.

129. Busy test—While the arrangement of multiple-line terminals accomplishes the purpose of permitting every operator to reach all the lines of an office, it creates another problem—confusion caused by different operators making more than one connection at a time with the same line—a condition which could not be tolerated. To guard against this confusion, the "busy test" is provided. As soon as a connection is made with a line at any section, the electrical condition of all the jacks of that line is so altered that an operator at any other section, in attempting to make a connection with the line, will be warned that a connection already exists. This warning is given by a click in the operator's receiver, when the sleeve of a multiple jack is touched with the tip of a calling cord plug. Figure 87 shows a simple schematic diagram of how this busy-test connection is established.

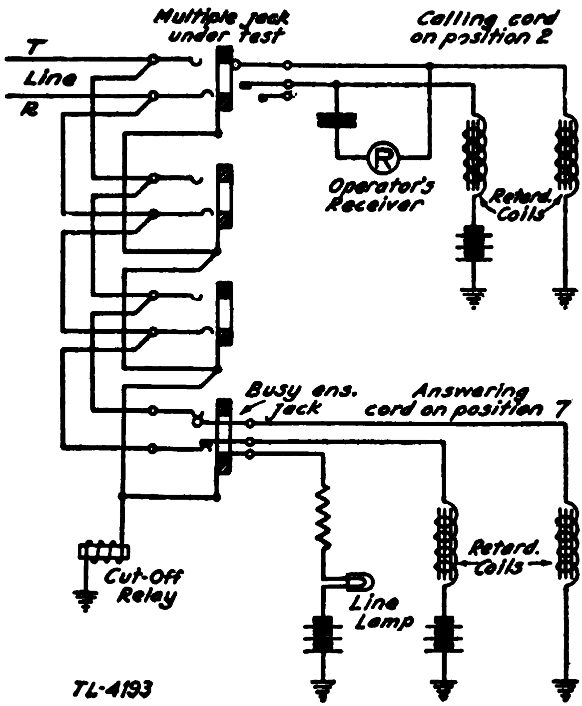

FIGURE 87.—Busy-test circuit.

130. Switchboard circuits.—Both multiple and nonmultiple switchboards are composed of a systematic and efficient arrangement of essential circuits, depending upon the kind and extent of service the board provides. The various types of line circuits, trunk circuits, cord circuits, and operator's telephone circuits employed in switchboards are taken up in other sections of this text.

131. Miscellaneous circuits.—In addition to the main communication circuits provided by switchboards. there are miscellaneous circuits on both muluiple and nonmultiple switchboards which perform auxiliary or supplementary functions. The following is a list of some of the more common miscellaneous circuits with a brief mention of their purpose:

Auxiliary relay.—To operate pilot lamp when any line lamp lights.

Pilot lamp.—To notify operator that a line lamp is lighted.

Fuse alarm.—To provide an audible signal when certain circuits are open due to blown fuses.

Night alarm.—To provide an audible signal when an incoming call appears on the switchboard.

Transfer key.—To group positions.

Ringing mains.—Wiring of ringing power to each position.

Emergency ringing.—Wiring of reserve ringing power.

Peg count.—To cut in meters to measure operator's load.

Position clock.—To operate clocks on each position.

Master clock.—To synchronize position clocks.

Supervisors.—To enable supervisors to check operators.

Monitoring.—To enable chief operators and others to check operator's work.

Busy-back.—To put a busy-back signal on plug-ended trunks.

Trouble tone.—To put a special tone on circuits which are out of order.

Howler.—Wiring of apparatus to generate howler tone.

Howler cord.—To provide for putting howler tone on a line to cause restoration of receiver.

Coin collect.—To enable operator to control pay stations.

There are many circuits available for any one make and type of switchboard, and any one installation will usually employ several of them. The number of different circuits required in any switchboard will vary with operating and service conditions. Each installation is covered by a specification, which makes reference to all drawings and wiring diagrams forming a part of it and covering the details of the circuits involved.

132. Western Electric 1–D switchboard.—Many present Signal Corps common-battery multiple switchboards are of the Western Electric 1–D type. On this switchboard it is usual to repeat the multiple every three positions; or, in other words, to wire the board with sections of three operator's positions each. Each section will then have 6 panels and will contain one complete appearance of calling jacks for all subscriber lines. On this form the switchboard has a capacity of 3000 lines and 300 trunks, each panel having an ultimate capacity of 120 answering jacks in strips of 10, or 160 in strips of 20. The 1–D board is very flexible, and it is often wired so as to repeat the multiple every two positions, resulting in four panel sections. With reduced sections the answering jack capacity of each panel is often reduced to 40, thus giving each operator 80-answering jacks to handle.

When the 1–D switchboard is wired with lamp associated multiple, with six panel sections, it has a capacity of 3000 lines and 60 trunks. The slight decrease in capacity is caused by the space required for the additional lamp jacks. With this arrangement there is the advantage of self-equalization of load and slight increase in speed of service, but as explained the lamp maintenance is higher and there is a greater drain on the battery.

133. Constructional features.—A section is a grouping of positions to secure one complete appearance of the multiple. It is the minimum initial installation of a multiple switchboard. A position is the subdivision of a switchboard designed to be handled by a single operator. A panel is a subdivision of the face equipment of a position, and has a width of one strip of jacks.

134. Arrangement of the multiple.—Figure 88 illustrates the panel arrangement of a multiple switchboard. Each section contains calling jacks of all lines served by the switchboard, the ultimate capacity in this instance being 7700 subscriber lines. There are seven panels and three operator's positions for each section. There must be sufficient operator's positions to allow each answering jack to appear once on the entire switchboard face. Should there be but four panels per section the capacity of the board would be 4400 subscriber lines. Such a decrease in the number of panels per section reduces the distance an operator will have to reach in completing a connection.

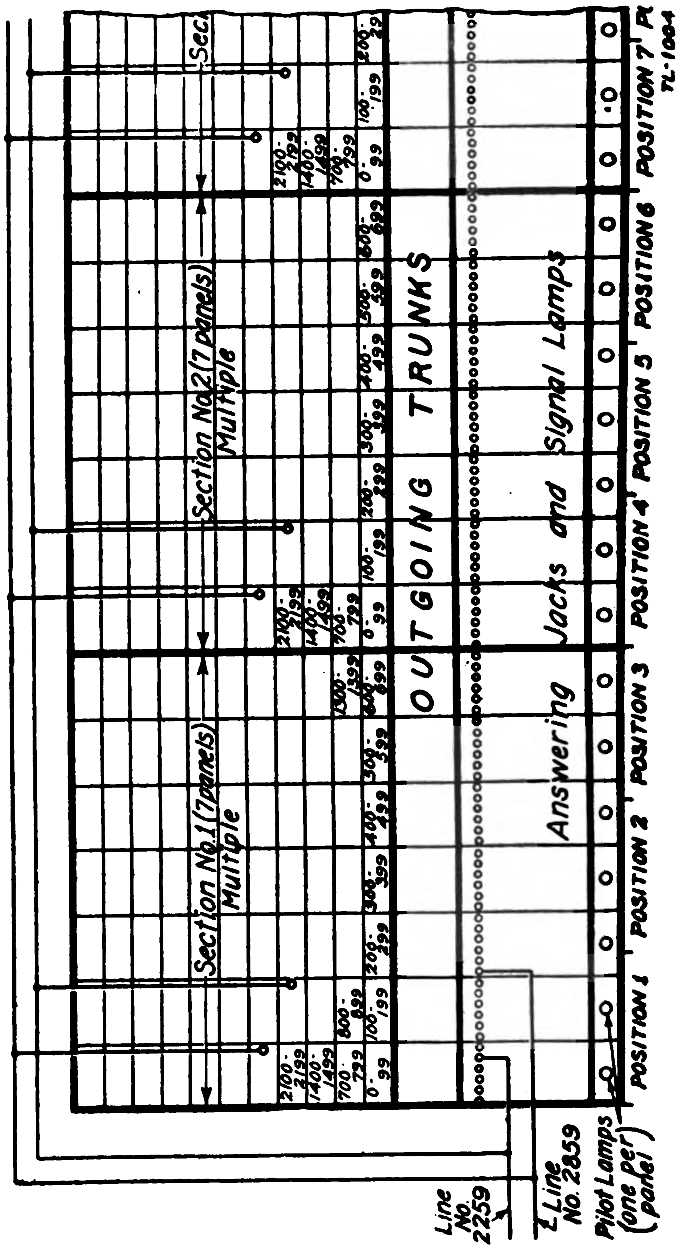

FIGURE 88.—Multiple panel arrangement.

135. Arrangement of jacks.—Answering jacks are usually in strips of 10, while multiple jacks on branch multiple switchboards are in strips of 20. The answering jacks are arranged for individual removable number plates to appear beside each jack. As has been mentioned, the numbering of the answering jacks is not consecutive, since the lines are shifted around so that approximately the same load is placed on each operator. The bottom position of the face equipment of each panel is occupied with answering jacks and line lamps. Next above them are the trunk multiple jacks numbered consecutively. To the left of each strip of trunk jacks there is a number plate in the stile strip, and above the jacks is a designation strip on which may be indicated the name of the exchange with which they afford connection. The remainder of the face of the panel is taken up with multiple jacks.

136. Multiple jacks.—Multiple jacks are grouped in banks of five strips or 100 jacks, as shown in figure 89. Each bank has a number plate in the stile strip to the left of it to indicate the number of the

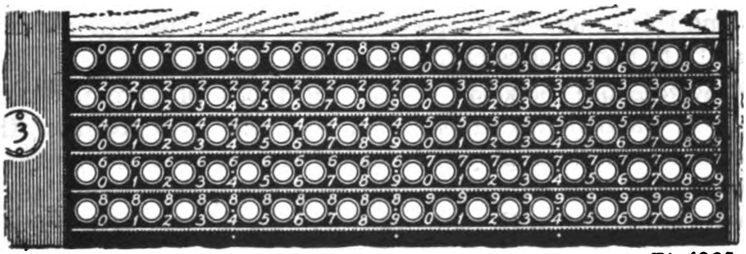

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FIGURE 89.—Multiple jack arrangement.

bank, and each bank is separated from the bank above and below by a $\frac{1}{16}$ inch strip of holly wood to segregate the bank. Strips of multiple jacks are inserted in the panel from the rear and are secured in position by discs known as jack fasteners.

137. Typical installations.—In numbers of positions and in positional equipments multiple switchboard installations will vary with the size of the post and the nature of the service. The number of answering jacks varies largely with the number of lines served. The number of multiple jacks varies with the number of answering jacks and the number of sections of the multiple. The number of trunks varies with the service requirements which are governed by several factors among which are: number of subscribers, size of system or system with which trunking is handled, number of exchanges to which trunk service is provided, amount of business which subscribers transact with those of connected exchanges, service of connected exchanges and the rate charged for trunks. The type of trunks used and the circuits employed vary with the nature of the

service given over them (subscriber, interoffice or toll), length of the trunk circuits and the type of equipment to which connected at the distant exchange.

138. Relay rack.—In larger installations there is little room in the switchboard positions for mounting relays. In such cases relay racks are provided for mounting the line and cut-off relays. The individual relays are mounted in groups of 10 or 20 on mounting plates of uniform length and these plates are bolted to a vertical channel iron framework known as a relay rack. The line and cut-off relays mounted on the relay rack are connected to terminals on the vertical side of the IDF (intermediate distributing frame) through switchboard cable. These same terminals of the IDF are cabled to the answering jack and lamp on the switchboard position. Thus, each answering jack and lamp is permanently associated with the relay-rack line equipment. This centralization of equipment provides a convenient place to introduce battery and ground. In modern practice one 24-volt battery lead is provided for each group of 120 line relays at the relay rack. Battery is fed to fuse panels and from there distributed through alarm fuses of the proper capacity to the various circuits.

139. Switchboard markings.—*a.* In all types of common-battery exchanges, particularly those with multiple switchboards, there are certain devices employed to assist the operator in giving the proper service. For example, lamp caps are obtainable in several different colors, and with many different markings engraved in the opal and filled with opaque paint. The different caps are used on the line and trunk lamps to distinguish between various classes of service. For example, a certain cap may be used to indicate that priority is to be given to the lines on which it is used, another type of cap may be used on lines denied trunk service, another on those denied toll service, another on those lines to be used for fire alarm service only, and so on for many other classes or combinations of classes of service.

b. Where lines are permanently disconnected or for one reason or other are temporarily out of service, it is desirable to be able to prevent an operator from plugging into the multiple jack. This is accomplished by inserting a signal plug in the appearances of the number in the multiple, and by using a proper color, it is possible to inform the operator why the line is not in service. In case of changes of subscriber's number the new number is marked on the signal plugs, and the old number is not used for another line until a new directory has been published.

c. There are four small holes around each multiple jack and by the use of certain colors of paint and combinations of holes, it is

possible to mark the multiple jacks to indicate a wide range of outgoing service conditions. To mark a series of jacks any one of which is available under the same calling number, such as a group of trunks to a branch exchange, a line of selected color is drawn below the entire group of jacks.

140. Questions for self-examination.—

1. In nonmultiple switchboard installations, how is future expansion provided for?
2. For what types or kind of installations are nonmultiple switchboards suitable?
3. What are the general limitations of nonmultiple switchboards?
4. What is meant by the term "multiple jack"?
5. What is the advantage of a multiple board?
6. Draw a diagram of a branch multiple showing the answering jack and at least one multiple jack with all equipment immediately associated with it.
7. What determines the subscriber's telephone number?
8. What change in wiring is made in a central office to change a subscriber's number?
9. What change in wiring is made to equalize the traffic load between operators' positions?
10. What is meant by a lamp associated multiple?
11. How is distribution of load effected on a lamp associated multiple switchboard?
12. By means of a diagram describe a series multiple arrangement.
13. In the series multiple why are cut-off springs used?
14. By means of a diagram explain the busy test used on a multiple switchboard.
15. Name six miscellaneous circuits found on a multiple switchboard.
16. Describe the arrangement of jacks in a multiple.
17. What is a relay rack?
18. What is the purpose of line lamp cap markings on a switchboard?

SECTION XV
COMMERCIAL MANUAL SWITCHING

Paragraph

141. Multioffice exchange, A and B switchboards.—Where the number of lines in an exchange exceeds the number which can economically be brought to a single switchboard, additional offices are established. In each office of such a multioffice exchange, there is an *A* switchboard to serve calls originating within the office area and a *B* switchboard to serve calls to subscribers within the office area which originate in other office areas of the exchange area, or in offices in other exchange areas. These calls may be routed to the called *B* switchboard either over direct trunk connections or via a centralized switching point. This switching point is known as a tandem office or, in cases of very long haul calls, a long distance office. An *A* switchboard is of the multiple type previously described and has outgoing trunks to all other offices within the exchange. These trunks are incoming to the *B* switchboard where they appear as plugs. A *B* switchboard is a trunking switchboard exclusively and has no cord circuits. In front of the operator appears the multiple of every subscriber in the office area, and on the cord shelf are plug-ended trunks from all other offices in the exchange.

142. Straightforward trunking.—On a call routed directly from the *A* switchboard in the calling office to the *B* switchboard in the called office, the usual method is by straightforward trunking. Take, for example, a call from Pershing 1872 to Cathedral 2536. The Pershing *A* operator answers the call and is given the number Cathedral 2536. She selects an idle trunk to the Cathedral office. This selection is made by means of the busy test–running the tip of the calling plug along the strip of jacks—or by observing a lighted lamp associated with an idle trunk. When the trunk is selected, the lamp associated with the next idle trunk lights. Connection to the selected trunk lights the lamp associated with the trunk at the Cathedral *B* switchboard. In response to the lighted lamp, the *B* operator connects to the trunk by manually depressing an assignment key or is automatically connected to the trunk by a relay in the trunk

circuit. An order tone consisting of two short impulses of high pitch called zip tones, is transmitted to the Pershing *A* operator. This advises the *A* operator that she may continue with the completion of her call, which she does by saying 2535 in this case. The Cathedral *B* operator than tests the line called and, if it is idle, connects to it. On connection to this multiple jack of the called subscriber, machine ringing is provided from the *B* board. The *B* operator's telephone is now disconnected from the incoming trunk by a relay in the sleeve of the trunk circuit. Supervision on calls trunked through *B* boards is of the through type and is returned to the *A* operator. It is the duty of the *A* operator to time this connection and to take it down in accordance with the signals of the supervisory lamps at the position. If the *B* operator finds the called line busy, the trunk plug is inserted into a jack which connects an interrupted tone, known as the busy-back, across the trunk line. The plug is left in the jack until the *A* operator takes down the connection as shown by the lighting of the supervisory lamp at the *B* switchboard.

143. Hundred-percent trunking.—In very large exchanges, the interoffice trunks take up so much room that the answering jack and multiple capacity is reduced below an economical figure. In this case 100-percent trunking is used and the subscriber multiple of the *A* board is removed, and in its place there is only the trunk multiple. In this case all calls are handled by both an *A* and a *B* operator. The *A* board here is exclusively an outgoing trunking board and the *B* board, as before, is exclusively an incoming trunking board.

144. Tandem offices.—Where the exchanges are so large that there is not room in the *A* board multiple for all of the *B* board trunks, or where it is uneconomical to establish groups of direct trunks between the offices involved, there is no direct connection between *A* and *B* boards. The tandem office is only a switching point used to connect one local exchange office with another, and serves the same purpose as an isolated switching central in military systems. When an *A* operator receives a call for a subscriber at an office to which she has no trunk, she routes it to the tandem office with which she is connected, and receives a series of three zip tones when the tandem operator comes in on the trunk. The *A* operator then gives the name of the called office. The tandem operator tests for an idle trunk to this office and puts the connection on through to the office of destination. When the called *B* operator comes in on a trunk to the tandem, there is a series of two zips and the *A* operator responds with the number of the station called. This routine sounds quite complex, but as a matter of fact it consumes but little time and has a high degree of accuracy, although each such call is handled by three operators.

145. Toll service.—Service between substations within an exchange is usually on a flat rate basis and is known as local service. Service between substations of different exchanges is handled on a charge per call basis and is known as toll service. This latter service is divided into two classes. The first class, used for traffic between exchanges which are generally not more than 50 miles apart, is is known as A-B Toll traffic. The second class, known as "long distance service", is used for traffic between more widely separated exchanges. For long distance service the toll board method is usually employed. A calling subscriber asks for "long distance". His local *A* operator then connects him to an outward operator at a toll switchboard over a recording trunk. This toll switchboard is one that handles long distance calls for a designated group of local offices. The outward operator fills out the toll ticket and secures a connection to the inward toll operator at the distant toll switchboard via a toll line. The outward operator then secures a connection to the calling party over a switching trunk to his local exchange. The switching trunk is a high grade circuit, and also provides 48 volts instead of 24 volts to the subscriber's telephone. These factors greatly improve transmission quality. The recording trunk over which the calling subscriber secured the original connection to the outward operator is then released. At the distant toll office the inward toll operator secures a connection to the called party via a toll switching trunk to her local exchange. The outward operator at the originating toll switchboard supervises and times the call. When the conversation is completed she takes down the connection and completes the toll ticket.

146. Questions for self-examination.—

1. What is an "A" switchboard?
2. What is a "B" switchboard?
3. Describe a call being placed between an "A" and a "B" switchboard.
4. What equipment appears on the face of a "B" board?
5. What equipment appears on the face of an "A" board?
6. What is meant bv straightforward trunking?
7. What is meant bv 100-percent trunking?
8. What is the advantage of 100-percent trunking?
9. What is a tandem office?

APPENDIX I
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TM 11-331	Switchboard BD-14
TM 11-332	Telephone Central Office Set TC-4
TM 11-333	Signal Corps Telephone EE-8-A
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APPENDIX II

GLOSSARY OF TERMS

The following definition of words and terms apply only to their usage in this text.

Alternating current—Current that periodically reverses in direction.

Alternator.—An a-c generator.

Ammeter.—A current meter with a scale calibrated in amperes.

Amplifier.—A device which, under control of a current or voltage of given characteristics, produces a larger current or voltage of similar characteristics.

Amplitude.—In connection with alternating current or any other periodic phenomena, the maximum value of the displacement from zero position.

Anode.—The terminal or electrode from which electrons leave an electron tube.

Antisidetone circuit.—A telephone circuit that materially reduces sidetone without reducing the output of the telephone; *without sidetone.* (See Sidetone.)

Armature.—The rotating assembly of a d-c motor or generator; also the movable iron part which completes the magnetic circuit in certain apparatus.

Attenuation.—The decrease in amplitude of electrical energy as it passes through a device or circuit.

Attenuator.—A device for producing attenuation; usually calibrated to produce known amounts of attenuation.

Battery.—A device for converting chemical energy into electrical energy; one or more cells.

Bell.—A device which will operate on either alternating or direct current (a-c or d-c) and give continued striking of a gong, producing a clear ringing sound.

Bias.—*Line bias.*—The effect on the length of telegraph signals produced by the electrical characteristics of the line and equipment. If the received signal is longer than that sent, the distortion is called marking bias; if the received signal is shorter, it is called spacing bias.

Applied bias.—A force (electrical, mechanical, or magnetic) exerted on a relay or other device which tends to hold the device in a given electrical or mechanical condition.

Break contact.—That contact of a switching device which opens a circuit upon the operation of the device.

Bridge.—A shunt path; a device used in the electrical measurement of impedance, resistance, etc.

Buzzer.—An electrical device producing a buzzing sound, usually by use of a vibrator.

Bypass.—A shunt path around some element or elements of a circuit.

Capacitance.—The ability or capacity to receive an electrical charge.

Capacitive reactance.—The effect of capacitance in opposing the flow of alternating current.

Capacitor.—A device for inserting the property of capacitance into a circuit; two or more conductors separated by a dielectric.

Carrier current.—A current used in the transmission of intelligence impressed upon it.

Carrier frequency.—The frequency of the carrier current.

Cathode.—The negative terminal or electrode in an electrolytic cell, vacuum tube, or other electrical apparatus, from which electrons flow.

Cell.—A combination of electrodes and electrolyte which converts chemical energy into electrical energy.

Channel.—A band of frequencies or a circuit within which communication may be maintained.

Characteristic.—A d stinguishing trait, quality, or property.

Circuit.—A closed path or mesh of closed paths which may include a source of emf.

Commutation.—The mechanical process of converting alternating current, which flows in the armature of d-c generators, to direct current as furnished to the load.

Commutator.—The part of d-c rotating machinery which makes electrical contact with the brushes and connects the armature conductors to the external circuit and accomplishes commutation.

Commutator ripple—The small pulsations which take place in the voltage and current of d-c generators.

Component.—A part of the whole; e.g. pulsating direct current (the whole) consists of an a-c component (one part) and a d-c component (another part).

Condenser.—Same as capacitor.

Continuity.—A condition of a circuit where a closed electrical path is obtained.

Contactor.—A device for closing and opening electrical circuits remotely; a magnetically operated switch.

Coupling.—Term used to represent the means by which energy is transferred from one circuit to another.

Cross.—A type of line trouble in which one circuit becomes connected to one or more other circuits.

Crossfire.—A condition where telegraph signals on one circuit cause interference in other telegraph or telephone circuits.

Crosstalk.—A condition where conversation on one circuit causes interference in other telephone circuits.

Current.—A flow of electrons in a circuit.

Cycle.—In a periodic phenomena, one complete set of reoccuring events.

Decibel.—A unit of transmission expressing a relation between input and output power; equal to ten times the common logarithm of the ratio of input to output power.

Demodulator.—A nonlinear device for removing the modulation component (usually voice frequency) from a modulated carrier wave.

Density.—Concentration of anything; quantity per unit volume or area.

Direct current.—Current which is constant in direction.

Differential.—Pertaining to, or involving, a difference; i.e., a differential current device is one which operates upon the basis of a difference in two current values.

Distortion.—An alteration or deformity of a wave form.

Drop.—*a. Switchboard drop.*—An electrically operated mechanical device on a switchboard line circuit which is used to indicate an incoming call.

b. Drop side of a circuit.—That side of the circuit toward the switchboard drop.

c. Drop wire.—The overhead wire connecting a subscriber station with either open wire or cable.

Electrode.—The solid conductors of a cell or battery which are placed in contact with the electrolyte; a conductor which makes electrical contact with a liquid, gas, or an electron cloud.

Electrolyte.—A solution in which, when traversed by an electric current, there is a liberation of matter at the electrodes, either an

evolution of gas or a deposit of a solid. Usually refers to the solution in a battery.

Electromagnet.—A core of magnetic material, such as soft iron, which is temporarily magnetized by passing an electric current through a coil of wire surrounding it, but loses its magnetism as soon as the current stops.

Electromotive force.—*emf*—Difference of electrical potential or pressure measured in volts.

Electron.—One of the negative particles of an atom.

Energy.—That capacity for doing work.

Equalizer.—A network having an attenuation complementary to that of a telephone line, for the purpose of equalizing the attenuation at the frequencies used.

Field of force.—Region in space within which a force is effective.

Filter.—A device for preventing the passage of current of certain frequencies while allowing currents of other frequencies to pass.

Flux.—The magnetic lines of force.

Force.—That which tends to change the state of rest or motion of matter.

Frequency.—In periodic phenomena the number of vibrations or cycles in unit time; in alternating current the number of cycles per second.

Function.—The duty or job performed by a device.

Fundamental.—A primary or necessary principle; basis; the lowest frequency component of a complex wave.

Fuse.—A circuit protecting device which makes use of a conductor which has a low melting point.

Gain.—The amount of amplification; negative attenuation.

Generator.—A device for converting mechanical energy into electrical energy.

Ground.—The contact of a conductor with the earth; also the earth when employed as a return conductor.

Grouping circuits.—Circuits used to connect two or more switchboard positions together so that one operator may handle the operation of those positions from his own operator's set.

Handset.—A telephone in which the transmitter, receiver, and a connecting handle form a single piece.

Harmonics.—Frequencies of exact multiples of a fundamental frequency.

Heat coil.—A protective device consisting of a coil of wire wound around a copper tube inside of which a pin is soldered. It is so de-

signed that if an excessive current passes through it for a period of time the heat generated will melt the solder, releasing the pin, and grounding the line.

Holding coil.—A separate coil of a relay which is energized by the operation of the relay and holds the relay operated after the original operating circuit is deenergized.

Howler.—An electromechanical device for the production of an audio-frequency tone.

Hybrid coil.—A multi-winding transformer designed to be used in a circuit where currents in one portion of the circuit induce voltages in all branches except certain designated ones in which no voltage is induced.

Impedance.—The total opposition to the flow of current, consisting of resistance and reactance.

Inductance.—Property of a circuit which opposes a change in current.

Induction.—The act or process of producing voltage by the relative motion of a magnetic field and a conductor.

Inductive reactance.—The opposition to the flow of alternating or pulsating current due to the inductance of the circuit.

Instantaneous value.—When a value is continually varying with respect to time the value at any particular instant is known as the instantaneous value.

Insulator.—A medium which will not conduct electricity.

Intermediate distributing frame.—A frame upon which the circuits from a switchboard and other apparatus are brought out to terminals.

Interposition trunks.—Trunks between different positions of a switchboard.

Jack.—In combination with a plug, a device by which connections can readily be made in electrical circuits.

Key.—A hand operated device for the rapid opening and closing of a circuit or circuits.

Leakage.—Term used to express current loss through imperfect insulation.

Level.—The amplitude of a signal as compared to that of a signal chosen as reference; in telephony, reference level is considered as that signal producing one milliwatt of power in a 600-ohm load; usually measured in decibels (db) above (+) or below (−) a reference level.

Lines of force.—A path through space along which a field of force acts. (Shown by a line or lines on a sketch.)

Loading coil.—A coil designed to be inserted in a line to add inductance to the line.

Loop.—*a. Subscribers loop.*—The pair of conductors connecting a subscriber's telephone with the main frame of the central office.

b. Loop mile, resistance of.—A pair of conductors between two points one mile distant, the resistance of the conductors connected in series.

Magnetic pole.—Region where the majority of magnetic lines of force leave or enter a magnet.

Magnetism.—The property of the molecules of certain substances, as iron, by virtue of which they may store energy in the form of a field of force, due to the motion of the electrons in the atoms of substance; a manifestation of energy due to the motion of a dielectric field of force.

Magnetomotive force.—*mmf*—The force which is necessary to establish flux in a magnetic circuit or to magnetize an unmagnetized specimen.

Main distributing frame.—A frame upon which are brought out the incoming cable or open wire lines to terminals and protectors.

Make contact.—That contact of a device which closes a circuit upon the operation of the device.

Megohm.—A unit of resistance; equal to one million ohms.

Microfarad.—Practical unit of capacitance; one-millionth of a farad.

Milliampere.—Unit of electric current; equal to one-thousandth of an ampere.

Milliammeter.—Current meter with a scale calibrated in milliamperes.

Modulator.—A nonlinear device for changing the amplitude (or frequency) of a carrier wave at a rate corresponding to the signal to be transmitted.

Multiple.—Parallel connection whereby any number of identical pieces of equipment may be connected into the circuit.

Mutual inductance.—Inductance associated with more than one circuit.

Network.—An electrical circuit made up of series or shunt impedances or combinations of series and shunt impedances.

Noise.—An electrical disturbance which tends to interfere with communication over the circuit.

Ohm.—Fundamental unit of resistance.

Ohmmeter.—A direct reading instrument for measuring resistance, calibrated in ohms.

Oscillator.—A device for producing electrical oscillations; an electrical circuit for converting direct current into alternating current.

Pad.—A network, consisting of resistance, connected so as to have a given amount of attenuation at all frequencies; usually symmetrical.

Parallel circuit.—A circuit in which one side of all component parts are connected together to one line while the other side of all components are connected together to another line.

Patching.—Temporarily connecting together two lines or circuits by means other than switchboard cord circuits.

Patching cord.—A cord terminated on each end with a plug, used in patching between circuits terminated in jacks.

Period.—The time required for the completion of one cycle.

Permanent magnet.—A piece of steel or alloy which has its molecules lined up such that a magnetic field exists without the application of a magnetomotive force.

Phantom circuit.—A telephone circuit which is superimposed upon two other circuits so that the two conductors of one circuit act combined as one conductor for the phantom circuit, and the conductors of the second circuit act as the other phantom conductor.

Plug.—In combination with a jack, a device by which connections can readily be made in electrical circuits.

Potential difference.—The degree of electrical pressure exerted by a point in an electrical field or circuit in reference to some other point; same as electromotive force or voltage.

Private branch exchange (P.B.X.).—A small private exchange acting as a branch of the main exchange for a subscriber with a large number of telephones between which considerable traffic is handled.

Protector.—A device to protect equipment or personnel from high voltages or currents.

Protectors, open-space cut-out.—A device consisting of two carbon blocks, one connected to one side of a line and the other to ground, separated by a narrow gap, designed to provide a path to ground for high voltages such as lightning, etc.

Pulsating current.—Current of varying magnitude but constant direction.

Receiver.—An electromechanical device for converting electrical energy into sound waves.

Rectifier.—A device for changing alternating current to pulsating current.

Reflection.—The returning of a portion of an electrical wave to the sending end of the circuit.

Relay.—A device for controlling electrical circuits from a remote position; magnetic switch.

Repeater.—A device for the retransmission of a signal, usually with amplification.

Repeating coil.—An audio-frequency transformer for transferring energy from one electrical circuit to another, usually one-to-one ratio with one side (line connection) arranged so that a center tap may be obtained for simplexing.

Resistance.—The opposition offered by a conductor to the passage of either direct or alternating current. That portion of impedance which causes power loss.

Resonance.—The condition of a mechanical device or electrical circuit adjusted to respond to a certain frequency.

Retardation coil.—A coil offering high impedance to voice frequency currents but low impedance to direct current.

Rheostat.—A variable resistance for limiting the currents in a circuit.

Ringer.—An audible signaling device which will operate only on alternating current to give a clear ringing sound.

Rotor.—The rotating part of an electrical device.

Self inductance.—Inductance associated with but one circuit.

Series circuit.—An electrical circuit in which the component parts are placed end-to-end and form a single continuous conductor; opposite of parallel.

Short.—A type of line trouble in which the two sides of a circuit become connected together.

Shunt.—A parallel or alternate path for the current in a circuit; usually with some impedance other than zero; not used with reference to trouble. (See Short.)

Side-band.—The band of those frequencies equal to the carrier plus the voice frequencies (upper side-band), or carrier minus the voice frequencies (lower side-band).

Sidetone.—That portion of the signal from a transmitter in a telephone which is returned to the receiver of that telephone.

Signal to noise ratio.—The ratio of the signal level on a circuit to the noise level of the same circuit.

Simplex.—A method of obtaining a telegraph channel by use of repeating coils or bridged impedances.

Singing.—Oscillations produced by feed-back in a circuit, especially in repeaters.

Space charge.—An electrical charge distributed throughout a space; such as a charge between the filament and plate of a vacuum tube.

Stator.—That part of an electrical device which remains stationary when in use.

Sub-cycle generator.—A frequency reducing device which furnishes ringing power at a sub-multiple of the power supply frequency.

Subscriber.—A person or organization to whom service is extended.

Subset.—The complete telephone equipment including handset, ringer, and other associated parts located at a subscriber station, exclusive of protective equipment.

Supervision.—The process of watching over the condition of a connection at a switchboard to determine when subscribers are through using the connection.

Switch.—A device for opening, closing, or rerouting an electrical circuit.

Switchboard.—A board containing apparatus for controlling or connecting electrical circuits.

Synchronism.—The state of being synchronous.

Synchronous.—Having the same period and phase; happening at the same time.

Tandem office.—A telephone office handling connections between smaller offices located in a group around it. It handles no direct connections to subscribers but serves only to connect one telephone office with another.

Telephone.—An instrument for the converting of speech into electrical waves for transmission and converting electrical waves to sound waves for reception.

Telering.—A frequency selector device for the production of ringing power; for the production of 20-cycle ringing power from a 60-cycle source it selects every third half-cycle of the input to be used as a half-cycle of the output frequency.

Terminal.—One end of an electrical circuit.

Transfer circuits.—Same as grouping circuits.

Transformer.—A device for raising or lowering a-c voltage.

Transmission.—The passing of energy through a conductor.

Transmitter.—Tnat part of a telephone which converts the sound

waves into electrical waves; usually consists of a diaphragm operated by the sound waves to compress a container of carbon granules, causing a change in resistance and thus in currents to correspond to the sound waves.

Transposition.—A rearrangement of the relative position of adjacent wires, to prevent losses or interference by induction.

Trunks.—A circuit between two switchboards, central offices, switchboard positions or other parts of a telephone plant, but not to any subscriber.

Varistor.—A combination of dissimilar metals in contact which give a nonlinear impedance.

Voice frequencies.—Those frequencies covered by the range of human voice.

Volt.—Unit of potential, potential difference, emf, or electrical pressure.

Voltmeter.—An instrument for measuring potential difference or electrical pressure, calibrated in volts.

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[A. G. 062.11 (7-15-42).]

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